Geo-Environmental Assessment

Former Brockhampton West Landfill, North of Harts Farm Way, Havant

Presented to **Clowes Developments (UK) Ltd**

Issued: August 2021

Delta-Simons Project No. 19-2099.04

deltasimons

Delta-Simons Environmental Consultants Limited
Head Office: 3 Henley Office Park, Doddington Road, Lincoln, LN6 3QR
Tel: 01522 882555 | www.deltasimons.com

recycle

INOGEN® ALLIANCE

Report Details

Client	Clowes Developments (UK) Ltd
Report Title	Geo-Environmental Assessment
Site Address	Former Brockhampton West Landfill, North of Harts Farm Way, Havant, PO9 1HS
Project No.	19-2099.04
Report Date	27th July 2021
Delta-Simons Contact	David Jackson (david.jackson@deltasimons.com)

Quality Assurance

Issue No.	Status	Issue Date	Comments	Author	Technical Review	Authorised
3	Final	27th August 2021	Updated with additional geotechnical data and receipt of Environment Agency comments	[redacted] Liane Baiao Consultant Ben Bradford Consultant	David Jackson Principal Rachel Mayne Principal	Richard Lawless Unit Director Mike Gennaro Associate

About us

Delta-Simons is a trusted, multidisciplinary environmental consultancy, focused on delivering the best possible project outcomes for customers.

Specialising in Environment, Health & Safety and Sustainability, Delta-Simons provide support and advice within the property development, asset management, corporate and industrial markets. Operating from across the UK we employ over 120 environmental professionals, bringing experience from across the private consultancy and public sector markets.

Delta-Simons is proud to be a founder member of the Inogen Environmental Alliance, enabling us to efficiently deliver customer projects worldwide by calling upon over 5000 resources in our global network of consultants, each committed to providing superior EH&S and sustainability consulting expertise to our customers. Inogen Environmental Alliance offers its clients more consultants, with more services in more countries than the traditional multinational consultancy.

Delta-Simons is a '***Beyond Net-Zero***' company. We have set a Science-Based Target to reduce our Scope 1 and Scope 2 carbon emissions in line with the Paris Agreement and are committed to reducing Scope 3 emissions from our supply chain. Every year we offset our residual emissions by 150% through verified carbon removal projects linked to the UN Sustainable Development Goals.

Therefore, our consultancy services to you are climate positive.

If you would like support in calculating your carbon footprint and playing your part in tackling the global climate crisis, please get in touch with your Delta-Simons contact above who will be happy to help.

Executive Summary

Brief	Delta-Simons Environmental Consultants Limited ("Delta-Simons") was instructed by Exton Estates on behalf of Clowes Developments (UK) Ltd (the "Client") to prepare a Geo-Environmental Assessment for Former Brockhampton West Landfill, North of Harts Farm Way, Havant, PO9 1HS (hereafter referred to as the 'Site'). The proposed use for the Site is the development of new employment units to provide up to 29,000 m2 (gross internal area) for flexible use across use Classes E (Light Industrial), B2 (General Industrial) and B8 (Distribution and Storage) with ancillary offices, car parking, service yards, drainage works, landscaping and associated works to prepare the Site for development. The purpose of this assessment is to identify the potential for land contamination issues to be present at the Site in the context of the proposed development, to support the planning application and to provide a geotechnical assessment.
Site Setting	The Site is currently an unoccupied parcel of grassland that previously was part of a wider landfill Site with limited areas of hardstanding in the centre.
Ground Conditions	A variable thickness of re-engineered cover system was recorded during the investigation, underlain by landfill waste, River Terrace Deposits and the Lewes Nodular Chalk Formation. The Site was divided into two landfill cells based on landfill waste composition, age and topography. Monitoring data suggests that the groundwater is tidally influenced and there are likely two groundwater bodies present across the Site, within the landfill waste and the Chalk. There is limited and variable vertical separation of the two groundwater bodies, with evidence of direct connectivity. The data indicates groundwater flows south / south-east toward the Langstone Harbour and Hermitage Stream.
Land Contamination Assessment	<u>Human Health</u> Asbestos was detected within the re-engineered cover system and landfill waste. The main exposure pathway is ingestion and inhalation. In general, potential health risks from impacted soils can be mitigated via the presence of buildings and hardstanding, which will satisfactorily address direct contact exposure pathways. Where areas of soft landscaping are proposed, the contaminant linkage can be broken by the installation of a clean cover system (existing soils/imported soils subject to appropriate further testing) . <u>Controlled Waters</u> Groundwater below the Site appears to have been impacted, at least in part as a consequence of the landfilling operations, as anticipated given the non-engineered 'dilute and disperse' nature of the landfilling. There is no evidence that the Site is having an unacceptable impact to the quality of the Hermitage Stream as it flows through the Site based upon the monitoring data obtained to date. Slightly elevated ammonium concentrations have been detected at low tide in the Hermitage Stream on both monitoring occasions, but at concentrations well below the relevant Environmental Quality Standard. The proposed development is considered to result in overall betterment in terms of the risks posed to surface and groundwater receptors due to the reduced infiltration rates from increased hardstanding provision compared to the present situation. <u>Built Environment</u> Design Sulphate Class DS-3 and ACEC Class AC-3 for soils and groundwater, is considered the most appropriate type of concrete to be used at the Site in order to resist chemical attack from elevated sulphate present in the soils (assuming mobile groundwater in potentially pyritic soils).

	However, the groundwater data suggests that the concentrations of ammonium (predominantly the perched groundwater within the landfill waste and River Terrace Deposits) present 'highly aggressive' conditions with regard to buried concrete and the guidance suggests that specialist advice should be sought in this instance. <u>Ground Gas</u> Monitoring of hazardous ground gases indicates elevated concentrations of both methane and carbon dioxide to be present on a Site-wide basis whilst gas flow rates are considered to be low. Based on the data obtained to date, there is considered to be a plausible risk from hazardous ground gases on the Site; protection measures will be required as part of the proposed development to adequately mitigate such risks to future Site users. It is considered prudent to adopt gas protection measures in line with Characterisation Situation (CS3) as a precautionary approach.
Geotechnical Assessment	It is understood that earthworks will be required as part of the proposed development, which will include the re-use of existing Made Ground soils (the existing re-engineered cover soils) in a Site wide cut and fill operation. These works need to be coordinated with the ground improvement specification and methodology adopted for the Site. In order to limit settlement over the lifetime of the development, a ground improvement solution is recommended across external areas of the Site. It is recommended that a ground improvement specialist is consulted to design a suitable solution at the Site, taking into consideration the proposed elevations and landfill thicknesses requiring treatment, environmental constraints and programme. A piled foundation and slab solution using pre-cast concrete driven piles with sacrificial cones transferring loads to competent Chalk geology may be suitable for the expected design loads, utilising both skin friction and end bearing capacity. The precise method of pile installation and applicability of proprietary systems, diameters and depths required would need to be informed based on the results of this investigation, by discussions with a piling contractor with suitable experience in Chalk. A preliminary conservative CBR value of 1% can be assumed for the ground model in its current form, however, is likely to be highly variable due to the compressibility of the ground model.
Recommendations	Based on the findings of this report, the following recommendations are made; ▲ Preparation of a Remediation Strategy, to mitigate any unacceptable risks specifically in relation to ground gas mitigation but also including clean cover in landscaped areas. This Strategy is likely to be required to support the discharge of relevant planning conditions that are likely to be imposed; ▲ Preparation of a Materials Management Plan (MMP); ▲ Preparation of a Piling / Foundation Works Risk Assessment; ▲ Detailed slope stability assessments, inclusive of additional supportive ground investigation are likely to be required for bunds A – AA and B – BB; ▲ Guidance should be sought from a specialist regarding the risk to buried concrete and the ammonium concentrations within the groundwater; and ▲ Further testing of the existing topsoil across the Site to ensure it is suitable for reuse within the clean cover system.
This is intended as a summary only. Further detail and the limitations of the assessment are provided within the main body of the Report.	

Table of Contents

1.0 INTRODUCTION 1
1.1 Appointment 1
1.2 Context & Purpose 1
1.3 Scope of Works 1
1.4 Aims 1
1.5 Existing Information 2
1.6 Limitations 2
2.0 SITE DETAILS 4
2.1 Site Setting 4
2.2 Preliminary Conceptual Site Model 6
3.0 SITE INVESTIGATION 9
3.1 Regulatory Consultation 9
3.1.1 Environment Agency (EA) 9
3.1.2 Havant Council (Local Authority) 9
4.0 GROUND SUMMARY 10
4.1 Introduction 10
4.2 Ground Model 10
4.2.1 East Cell 10
4.2.2 West Cell 15
4.3 Visual and Olfactory Evidence of Contamination - Soils 18
4.4 Groundwater 19
4.4.1 Strikes During Investigations 19
4.4.2 Levels During Monitoring Programme 20
4.4.3 LevelLogger™ Data 22
4.4.4 Water Infiltration in the Landfill Waste 23
4.5 Visual and Olfactory Evidence of Contamination - Groundwater 26
4.6 Low-Flow Water Quality Data 26
4.7 Material Properties 27
4.7.1 East Cell 28
4.7.2 West Cell 29
4.7.3 Earthworks Material Classification 30
4.8 Geochemical Testing 30
4.9 Forensic Waste Testing 31
4.10 Ground Gas Data 32
4.10.1 Bulk Gases & Flow Rates 32
4.10.2 Continuous Monitoring 33
4.10.3 Atmospheric Pressures 34
4.10.4 Purge and Recovery Test 35
5.0 GEOTECHNICAL ASSESSMENT 36
5.1 Summary of Development Proposals 36
5.2 Earthworks 36
5.3 Settlement Discussion 37
5.4 Foundations (Buildings) 39
5.4.1 Piling 39
5.5 Floor Slabs 40
5.6 Ground Improvement Techniques (External Areas) 40
5.7 Proposed Bunds and Slopes 40
5.8 Retaining Structures 41
5.9 Groundwater 42
5.10 Roads and Pavements 42
5.11 Excavations & Obstructions 42
5.12 Chemical Attack on Buried Concrete 42
5.13 Geotechnical Risk Register 43
6.0 GENERIC QUANTITATIVE RISK ASSESSMENT 44
6.1 Introduction 44
6.2 Human Health GQRA 44

6.2.1 Risks from Soil Sources 44
6.2.2 Risks from Groundwater Sources 46
6.2.3 Risks from Non-Aqueous Phase Liquids (NAPL) 46
6.3 Controlled Waters/Water Environment GQRA 47
6.3.1 Groundwater Results 47
6.3.2 Surface Water Results 47
6.3.3 Groundwater and Surface Water Discussion 48
6.3.4 Rainwater Infiltration Modelling 62
6.3.5 Light Non Aqueous Phase Liquid (LNAPL) 63
6.4 Built Environment 63
6.4.1 Potable Water Supply Pipes 63
6.4.2 Building Materials 64
7.0 BULK GROUND GAS RISK ASSESSMENT 65
7.1 Ground Gas Conceptual Site Model 65
7.1.1 Sources 65
7.1.2 Pathways 65
7.1.3 Receptors 66
7.2 Duration & Extent of Monitoring 66
7.3 Ground Gas Risk Assessment 68
7.3.1 Background 68
7.3.2 Flow Rates 68
7.3.3 Groundwater 69
7.3.4 Worst Case Low Pressure/Pressure Fall Event Scenario 70
7.3.5 Biodegradable Material Content 70
7.3.6 Spot Monitoring and Continuous Monitoring - Gas Screening Value (GSV) 71
7.3.7 GGS PRT® 73
7.3.8 Risk Assessment 75
7.4 Ground Gas Risk Mitigation 75
7.5 Radon 76
7.6 Organic Vapours 76
8.0 REVISED CONCEPTUAL SITE MODEL 77
9.0 CONCLUSIONS & RECOMMENDATIONS 79
9.1 Geotechnical Summary 79
9.2 Contamination Issues 79
9.2.1 Human Health 79
9.2.2 Controlled Waters 80
9.2.3 Ground Gas 80
9.3 Recommendations for Supplementary Work 80

Drawings

Drawing 1	Site Layout Plan, Harts Farm Way, Havant *by Michael Sparks Associates* (Ref: 31383/FE/37)
Drawing 2	WYG Exploratory Hole Location Plan
Drawing 3	Earthworks Analysis *by Readie Construction Limited* (Ref: RCL-CP143-EW-051)
Drawing 4	Indicative Landscape Sections, Harts Farm Way, Brockhampton West, Havant *by Pegasus Design* (Ref: P21-1528_16)

Figures

Figure 1	Exploratory Hole Location Plan
Figure 2	Landfill Waste - Proven Depth to Base Plan
Figure 3a	SPT vs Depth Plot (m bgl) – West Cell
Figure 3b	SPT vs Depth Plot (m AOD) – West Cell
Figure 4a	SPT vs Depth Plot (m bgl) – East Cell
Figure 4b	SPT vs Depth Plot (m AOD) – East Cell
Figure 5	Granular Re-Engineered Cover System Material Location Plan
Figure 6	Groundwater Contour Plan (Round 4 Groundwater Monitoring)

Appendices

Appendix A	Limitations
Appendix B	Geological Cross Section
Appendix C	CPT Data Interpretation
Appendix D	Geotechnical Risk Register
Appendix E	Groundwater Chemical Analysis Summary Table
Appendix F	Ammoniacal Nitrogen Data Summary
Appendix G	HR Wallingford IH124 Calculations Sheet – Total Site Area
Appendix H	HR Wallingford IH124 Calculations Sheet – Proposed Development

1.0 Introduction

1.1 Appointment

Delta-Simons Environmental Consultants Limited ("Delta-Simons") was instructed by Exton Estates on behalf of Clowes Developments (UK) Ltd (the "Client") to prepare a Geo-Environmental Assessment for Former Brockhampton West Landfill, North of Harts Farm Way, Havant, PO9 1HS (the "Site").

1.2 Context & Purpose

The aim of the study was to complete a geo-environmental assessment of the proposed development area. The investigation has obtained information regarding ground conditions, from which risks to end-users, the environment and structures have been assessed, with mitigation measures suggested where necessary.

The investigation has also gathered geotechnical information to inform comment on the preliminary design of foundations and infrastructure. The report provides recommendations for further work (where appropriate) based on the findings of the investigation.

The proposed use for the Site is the development of new employment units to provide up to 29,000 m2 (gross internal area) for flexible use across use Classes E (Light Industrial), B2 (General Industrial) and B8 (Distribution and Storage) with ancillary offices, car parking, service yards, drainage works, landscaping and associated works to prepare the Site for development.

Hardstanding areas to facilitate carparking and yards are proposed to be situated around the buildings with areas of soft landscaping/bunds towards the perimeter of the Site. Entrance to the Site will be via Harts Farm Way with ease of access to the heavy goods vehicle (HGV) docking stations. A cut and fill operation will be required to facilitate the proposed units. A copy of the proposed development plans is included as Drawing 1.

1.3 Scope of Works

The scope of the investigation and layout of this report has been designed with consideration of guidance on Land Contamination: Risk Management pages of the GOV.UK web pages, the relevant requirements of the National Planning Policy Framework 2019 (NPPF) (paragraphs 170 & 178-180)[1] and the Planning Practice Guidance (Land Affected by Contamination)[2].

The project was carried out to an agreed brief as set out in Delta-Simons' proposal dated 9th February 2021 (ref.19-2099.04). The scope of works is outlined in Section 3.2.1.

Specific sections of this report may generally follow guidance set out in Eurocode 7 for a Ground Investigation Report (GIR), as defined in BS EN 1997-1:2004 and BS EN 1997-2:2007. Eurocode 7 includes specific guidance on the number and spacing of investigation positions, methods of investigation and sample quality to be achieved which may not have been met by this investigation. The report also includes information which may support a Geotechnical Design Report (GDR) as defined in BS EN 1997-1:2004; however, unless otherwise explicitly stated, the investigation has not been undertaken in accordance with Eurocode 7 and the preliminary geotechnical interpretation, assessments, risk register and recommendations presented within this report may not meet the full requirements of a GDR.

1.4 Aims

The following aims were agreed with the Client as part of the pre investigation Client meetings:

- Achieve an institutionally acceptable assessment;
- Provide a robust understanding of the ground model;
- Provide an environmental risk assessment incorporating consideration of sensitive receptors (principal aquifer, Langstone Harbour – Special Area of Conservation [LH-SAC]);

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf
[2] https://www.gov.uk/guidance/land-affected-by-contamination

- Inform foundation design for foundations, floor slabs and retaining walls (including piles);
- Inform mass balance and earthworks design for the redevelopment;
- Inform re-use/disposal/management of the waste materials on Site;
- Inform the need for and scope of mitigation measures for the constraints presented by Site conditions;
- Provide data which supports an assessment of risks to the principal aquifer and LH-SAC;
- Support the future planning applications for the development; and
- Support regulatory engagement.

1.5 Existing Information

Delta-Simons has reviewed and included pertinent information and data from the provided *Draft Phase II Environmental Audit* by WYG dated August 2017 (ref: A102760).

To date, Delta-Simons have produced the following reports for the Site:

- *Preliminary Geo-Environmental Risk Assessment* by Delta-Simons dated February 2021 (ref: 19-2099.01); and
- *Factual Site Investigation Report* by Delta-Simons dated June 2021 (ref: 19-2099.04).

1.6 Limitations

The assessment is limited to the scope agreed within the proposal for the works. General limitations associated with this report are provided in Appendix A. In addition, there are the following specific limitations that apply to this assessment:

- Due to the presence of slow worms on-Site and the drilling works commencing during their hibernation period, the drilling locations were limited to the pre-existing tracks where the grass was already short. This, as well as the proposed exploratory hole location plan was agreed with the project ecologist Applied Ecology. Whilst this constraint was present, Delta-Simons do not consider the placement of the exploratory holes to have impacted the overall aims and objectives of the ground investigation;
- Dense vegetation around the perimeter of the Site limited access to these areas;
- Steep slopes on-Site limited the placement of the borehole locations due to the requirement for a level, stable platform for the drilling rig;
- Up to 13 cone penetration test (CPT) locations were proposed but, due to refusals on obstructions within the waste mass, only nine locations reached the required depths. Additional locations were attempted within the vicinity of the refused CPT locations where obstructions had been encountered. In total 16 CPT attempts were made across the Site;
- The Chalk bedrock was weaker than previously recorded on-Site so, in order to provide sufficient information for the structural engineer, the rotary boreholes were progressed deeper than initially proposed. As such, in order to keep within the programme of works, the three locations proposed for dynamic sampling were instead advanced by rotary open hole methods;
- The Chalk recovered during the drilling works was logged as structureless and so, the proposed geotechnical testing schedule had to be amended to suit the geology *i.e.* very limited rock core was recovered and so predominantly soil based testing was undertaken;
- The proposed exploratory hole location plan for the borehole, trial pit and CPT locations was approved by the structural engineer at the time of the investigation;
- The overhead power line on-Site, adjacent to the southern boundary, required a 15 metre standoff zone for all plant and vehicles. As such, no exploratory locations were undertaken within this standoff zone; and
- Delta-Simons could not access borehole locations RO101 to RO106, installed within the waste mass, during round three of the ground gas and groundwater monitoring programme. This was due to continuous

monitoring equipment being installed in those locations, that prevented access to the standpipe and could not be removed.

2.0 Site Details

2.1 Site Setting

A summary of the current Site status, environmental setting and key historical features is presented below. This has been summarised from the existing report(s) listed in Section 1.5 which should be consulted for further detail.

Co-ordinates	Centred approximately at National Grid Reference 470150, 105700.	**Elevation**	3.0 – 14.0 m AOD
		Area	8.3 Ha
Site Location	The Site is located to the south of the Havant Bypass (A27) towards the western outskirts of Havant, approximately 7.0 km north-east of Portsmouth.		
Current Site Use	The Site is currently an unoccupied parcel of grassland that previously was part of a wider landfill Site with limited areas of hardstanding in the centre. The Site comprises a small access road branching from Harts Farm Way in the southern central area of the Site. The Site is occupied by trees and shrubs along the perimeter. The Hermitage Stream is present adjacent to the eastern boundary of the Site with a sheet pile wall, understood to have been constructed circa 1969 as an initial stage of the land reclamation and landfilling process separating the Site and the watercourse.		
Proposed Development	The proposed use for the Site comprises the development of new employment units to provide up to 29,000 m^2 (gross internal area) for flexible use across use Classes E (Light Industrial), B2 (General Industrial) and B8 (Distribution and Storage) with ancillary offices, car parking, service yards, drainage works, landscaping and associated works to prepare the Site for development. Hardstanding areas to facilitate carparking and yards are proposed to be situated around the buildings with areas of soft landscaping/bunds towards the perimeter of the Site. Entrance to the Site will be via Harts Farm Way on the southern boundary with ease of access to the heavy goods vehicle (HGV) docking stations. A cut and fill earthworks operation will be required to facilitate the proposed units. The latest development proposal is presented as Drawing 1. Identified human and built environment receptors (R) relevant to the proposed development comprise: ▲ Construction workers. ▲ Third parties during construction (adjacent Site users and adjacent residents). ▲ Future Site users and maintenance workers. ▲ The Built Environment (new buildings and infrastructure/utilities).		
Environmental Setting	The nearest surface water feature is Hermitage Stream that flows along the eastern boundary of the Site and flows southwards into Storehouse Lake (Langstone Harbour). This is a tidal watercourse with flow direction reversing during rising tides. Langstone Harbour is a site of significant ecological importance with designations including a Natura 2000 site, Ramsar Site, a Site of Special Scientific Interest (SSSI), a Special Area of Conservation (SAC) and a Special Protection Area (SPA).		
Key Historical Features	Historically, the Site comprised tidal / estuarine mud flats until circa 1969, when the area was subjected to land reclamation via waste disposal. Authorised waste included concrete waste, construction and demolition wastes, household waste and incinerator		

	residues. Landfilling ceased at the Site by circa 1987 and the Site was briefly used as playing fields, after which no further developments have taken place. It is understood the landfill extended beyond the Site boundary and was designed as a 'dilute and disperse' system, a common concept for landfills predating the early 1990s. These systems usually relied on groundwater to dilute the leachate and disperse into the underlying strata, with no formal lining / containment system for gas or leachate incorporated into the design.
Summary of Previous Reports	A summary of the *Draft Phase II Environmental Audit* by WYG dated August 2017 (ref: A102760) is included below.
Environmental Audit by WYG	<u>Ground Conditions</u> The Site investigation comprised the drilling of six boreholes to depths of up to 35.0 m below ground level (bgl), 10 window sample boreholes (to approximately 5.0 m bgl) and 11 trial pits (to a maximum depth of 4.0 m bgl). Environmental and geotechnical soil samples were taken, and a ground gas and groundwater monitoring scheme was conducted over a period of six weeks comprising six visits. Ground conditions encountered during the investigation consist of the following: ▲ A thin layer of topsoil (up to 0.3 m bgl); ▲ A consistently thick layer of Made Ground up to 11.5 m bgl comprising a cover layer (up to approximately 5.0 m in thickness but highly variable) and an underlying landfill layer (ranging from approximately 4.5 – 7.4 m thick across the Site); ▲ River Terrace Deposits comprising sand and gravel recorded a maximum thickness of 5.0 m in the east of the Site; ▲ Alluvium comprising sandy/gravelly clay recorded a maximum thickness of 3.5 m towards the west of the Site; and ▲ Chalk was encountered beneath the superficial deposits across the entirety of the Site to the base of each intrusive borehole (35.0 m bgl). The Made Ground consisted of two distinct layers: 'cover material' and 'landfill'. The general nature of the cover material comprised sandy gravelly clay with minor anthropogenic materials including brick and gravel. The underlying landfill layer recorded a higher proportion of anthropogenic materials including paper, wood, plastic, metal and glass. Groundwater strikes were recorded in both landfill and superficial strata at depths ranging between 3.9 and 11.5 m bgl. During return monitoring visits, depth to groundwater was typically in excess of 5.0 m and was predominantly indicated to sit towards the base of the Made Ground or top of the Chalk. <u>Contamination Findings</u> Elevated concentrations of ground gases (maximum 98% methane, 46% carbon dioxide) have been measured within monitoring wells across the Site, with one elevated flow rate of 31.1 l/hr within the landfill material; however, flow rates were generally between -1 to 1 l/hr. Asbestos fibres were detected in 15 of 40 soil samples collected from the Made Ground (both cover material and landfill). PAH contamination (dibenzo(ah)anthracene) was identified in the topsoil in one location which was only marginally above the commercial GAC. Hydrocarbons, ammoniacal nitrogen and cyanide were detected in water samples screened from the landfill, and also in one Chalk groundwater sample.

	Geotechnical Assessment Geotechnical testing included Particle Size Distribution tests (PSDs), Atterberg limits and undrained triaxial test. Alluvium shear strengths were reported at 29 kPa. Delta-Simons has included the relevant WYG data within our 2021 assessment where appropriate to provide the fullest possible current understanding of prevailing ground conditions. A copy of the report is included as Appendix G within the *Preliminary Geo-Environmental Risk Assessment* by Delta-Simons and the exploratory hole logs are included as Appendix B within the *Factual Geo-Environmental Investigation Report* by Delta-Simons.

2.2 Preliminary Conceptual Site Model

A summary of the preliminary Conceptual Site Model is presented below.

Source(s)	Potential Contaminants of Concern (CoC)	Pathway(s)	Receptor(s)	Preliminary Risk Rating
Potential Made Ground deposits associated with cover material and re-engineering works on Site	Asbestos, heavy metals, total petroleum hydrocarbons (TPH) and polyaromatic hydrocarbons (PAHs)	P1, P2, P3, P4, P5	R1, R2, R3, R4, R6	**Low to Moderate Risk**
Historical Landfill Site	Main Risk Drivers – Domestic/Trade Waste (Site Wide) Leachate and ground gas generation potential. Secondary Risk Drivers (Localised based on tipping of unauthorised materials) Asbestos, heavy metals, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAHs), semi volatile organic compounds (SVOCs) and volatile organic compounds (VOCs)	P1, P2, P3, P4, P5, P6	R1, R2, R3, R4, R5, R6	**Moderate to High Risk**

Pathways:

- P1 - Direct contact, ingestion or inhalation of soil bound contaminants / dust during or following redevelopment.
- P2 - Inhalation of organic vapours associated with contamination.
- P3 - Migration of ground gas / vapours into on-site buildings causing asphyxiation or risk of explosion.
- P4 - Leaching of contamination into groundwater followed by migration of groundwater to the wider groundwater environment or discharge to surface waters.
- P5 - Direct contact between aggressive ground conditions and new infrastructure.
- P6 – Preferential pathway created by installation of piles allowing migration of contamination into the Chalk aquifer and upward migration of ground gases to the surface

Relevant potential receptors are considered to include:

- R1 - Construction workers.
- R2 - Third parties during construction (adjacent Site users and adjacent residents).
- R3 - Future Site users and maintenance workers.

- R4 – Hermitage Stream leading to Storehouse Lake.
- R5 - The underlying Chalk Principal Aquifer.
- R6 - The Built Environment (new buildings and infrastructure / utilities).

3.0 Site Investigation

Delta-Simons carried out intrusive investigation work from 15th February to 1st April 2021 to assess the potential linkages identified in the outline conceptual model (see Section 2.2 above) and to provide geotechnical information.

Please refer to the Factual Site Investigation Report by Delta-Simons, dated June 2021 (reference: 19-2099.04) for further information regarding health and safety, scope and rationale.

3.1 Regulatory Consultation

A regulatory consultation document was prepared and circulated to the relevant contacts within the Environment Agency and Local Authority on the 8th February 2021 to provide a summary of the proposed Site investigation, monitoring and assessment of this Site. The main specific points raised by the regulators are summarised below:

3.1.1 Environment Agency (EA)

- The EA considers that the most significant controlled waters risk posed by the Site is the potential for lateral migration of contaminants, from the leachate/waste mass, to Langstone Harbour SAC. They required that this should be a key consideration of the investigation. The EA also expressed particular concern to the introduction of nitrogen species (such as ammonia) into the stream/Langstone Harbour.
- From a controlled waters perspective determining if any containment of the landfill from geology and the sheet pile wall would be required to consider the impact on Langstone Harbour.
- They recognised that given the site setting, that the Chalk Principal Aquifer it is unlikely to have significant resource potential however, they would have concerns if gross contamination was present. The EA's principal concern is whether the Chalk is acting as a pathway to sensitive surface water receptors, principally Langstone Harbour.
- Characterisation of both the perched waters/leachate within the waste mass (particularly the leachate presence) is extremely important.
- Overall, the EA considered that the proposed scope of works for the investigation and assessment of the Site are broadly appropriate, though dependent on any results of any investigations, further work may be required.
- Recommended sampling of the Hermitage Stream at falling tide at up, mid and downstream monitoring points.

3.1.2 Havant Council (Local Authority)

- Welcomed the proposal to install continuous ground gas monitors to reliably characterise the gas regime at this Site and confirmed that the distribution & duration of monitoring to be appropriate.
- The dual installation of wells within the wastes and Chalk are considered appropriate providing that construction minimises the risk of cross contamination e.g. appropriate seals are installed between the waste and superficial/Chalk material below and also between the slotted pipe sections.
- Also recommended sampling within the Hermitage Stream to assist the controlled waters risk assessment.

The above comments were considered and catered for within the Site investigation design, monitoring and assessment phases of this project.

4.0 Ground Summary

4.1 Introduction

The sections below summarise the ground and groundwater conditions encountered during the site investigation. This section will also include data from the Draft Phase II Environmental Audit prepared by WYG (August 2017). The WYG exploratory hole location plan is included as Drawing 2 and the exploratory hole logs are included as Appendix B within the *Factual Geo-Environmental Investigation Report* by Delta-Simons.

4.2 Ground Model

The ground conditions were variable across the Site, both in composition and proven thickness of the various strata. With regard to the landfill, based on the topography of the Site and the general composition of the waste, the Site can be generally split into two landfill 'cells' (refer to Figure 1). These cells are indicative and are assumed to extend to the boundaries of the Site specifically the exiting road network and the stream to the east. The wider landfill (including other likely cells for disposal) is known to extend to the south and west.

As such, for the purpose of this section, the Site will be discussed as two separate cells – east and west.

4.2.1 East Cell

A summary of the observed ground conditions at the Site is provided below.

Summary of Observed Ground Conditions				
Strata	**Typical Strata Description**	**Depth Range of Strata Base (m bgl)**	**Maximum Proven Thickness (m)**	**Comments**
Made Ground: Topsoil	Soft slightly sandy slightly gravelly CLAY.	*0.1 (TP115) – 0.39 (RO104)*	*0.39 (RO104)*	*Encountered in every location in the east cell.* *Topsoil generally appears most thin in the east and thickest in the north-west of the east cell.* *Composition generally similar across the east cell.*
Made Ground: Re-engineered cover system (Granular)	Gravelly clayey SAND. Gravel of sandstone, flint, brick.	*0.35 (TP114) – 2.35 (RO109)*	*1.73 (TP113)*	*Encountered in 13 locations across the east cell.* *Generally, appears to be thickest in the south-east of the east cell.* *Primary constituent was SAND across every location with varying percentages of secondary constituents.* *Occasional cobbles and boulders encountered generally in the south and east.* *Of the 13 locations that recorded granular material within the re-engineered cover system, in five, the cover system was entirely comprised of granular material rather than cohesive and granular stratum.* *Therefore, approximately 38% of the cover system within the 13 locations are comprised entirely of granular material.*

Summary of Observed Ground Conditions				
Strata	**Typical Strata Description**	**Depth Range of Strata Base (m bgl)**	**Maximum Proven Thickness (m)**	**Comments**
Made Ground: Re-engineered cover system (Cohesive)	Firm gravelly CLAY. Gravel is of flint, brick and Chalk. Soft slightly gravelly SILT. Gravel is of flint, brick and Chalk.	*0.4 (TP118) – 2.1 (DS103)*	*1.8 (DS103)*	*Encountered in 16 locations across the east cell. The cohesive capping layer was significantly more common that the granular capping layer.* *Thicknesses varied across the east cell.* *Silt encountered in only five locations across the east cell – predominantly clay.*
Made Ground: Suspected Original Re-engineered cover system	Soft to stiff slightly sandy or slightly gravelly SILT. Gravel of flint.	*2.0 (TP119) – 4.0 (TP111)*	*0.8 (TP110)*	*Encountered in five locations across the east cell, underlying and overlying the landfill waste.* *Identifiable from the landfill waste due to the greater firmness in comparison and significant lack of waste content.*
Made Ground: Landfill Waste	Landfill recovered as frequent wood, occasional plastic, rare leather, styrofoam and rubber with approximately 60% matrix of very soft dark grey gravelly CLAY. Gravel of clinker and brick. Landfill recovered as frequent wood, plastic, occasional metal, glass, rare carpet, rare rubber, styrofoam, asphalt fragments, paper, cable, textile and cardboard with approximately 70% matrix of black SAND with ash (approximately 20%) and a low cobble content. Cobbles of concrete.	*9.0 (DS101) – 13.3 (RO106)*	*12.4 (RO106)*	*Encountered in every location.* *Landfill waste thickness increases / decreases in line with the topography of the cell – a steep sided dome.* *Thinnest along the eastern boundary.* *Composition highly variable across the cell – particularly percentage of matrix[3].* *Landfill waste in east cell was generally higher in 'household' waste content and comprised a higher proportion of waste showing little evidence of decomposition – particularly in the shallower trial pit locations.*
Made Ground: Reworked River Terrace Deposits (RTD)	Brown sandy GRAVEL of flint with occasional plastic and wood fragments.	*14.1 (RO106)*	*0.2 (RO106)*	*Encountered in one location (central-south).* *Distinguishable by significant decrease in waste content in comparison to the landfill waste, with the typical composition of the RTD across the Site.*
River Terrace Deposits	Light orange and cream slightly sandy GRAVEL of flint and Chalk.	*10.5 (RO109) – 14.4 (RO105*	*3.7 (RO105)*	*Encountered in six locations (DS101 to 103, RO104, RO105 and RO109). All locations except RO104*

[3] The term matrix refers to the percentage of 'soil' within the waste. The percentage of matrix ranged from 15 to 95%.

Summary of Observed Ground Conditions				
Strata	**Typical Strata Description**	**Depth Range of Strata Base (m bgl)**	**Maximum Proven Thickness (m)**	**Comments**
				are located along the eastern boundary of the Site. *Thickness of RTD varies between 0.9 m and 3.7 m bgl with the superficial deposits generally thinner in the south-east corner of the east cell.*
Alluvium	-	-	-	*Not encountered.*
Lewes Nodular Chalk Formation (Grade Dc)	Structureless CHALK composed of white slightly sandy silty GRAVEL of Chalk and rare flint. Clasts are upper end of weak medium density white of Chalk.	*Base not proven.*		*All Chalk encountered was recorded as structureless with interbedded cohesive and granular stratums.* *SPTs were variable but generally increased with depth.*
Lewes Nodular Chalk Formation (Grade Dm)	Structureless CHALK composed of white slightly sandy slightly gravelly SILT. Gravel is very weak low density white of Chalk and rare flint.			

A cross section for the Site is included as Appendix B.

The depth of the landfill waste has been proven across the Site however, the exact lateral extents are unknown due to restrictions in the placement trial pits/boreholes at the time of the investigation. As such, it is considered prudent to assume that that the landfill material was tipped up to the boundaries of the Site.

The thickness of the re-engineered cover system, landfill and superficial deposits vary across the Site, as can be seen in the cross section overleaf. The re-engineered nature of the cover system was considered within the Preliminary Risk Assessment undertaken by Delta-Simons (reference: 19-2099.01). Aerial imagery indicated that, at various stages, the cover system was in the process of earthworks movement and placement. As such, Delta-Simons consider the most representative interpretation for the covering material is 're-engineered cover system'.

Granular re-engineered cover system material was encountered across the east cell, in almost the same number of exploratory locations as its cohesive counterpart. This is illustrated in Figure 5. This indicates the composition of the re-engineered cover system is not uniform across the Site, with regard to composition and also thickness. Furthermore, based on the large percentage of granular material within the overall composition of the re-engineered cover system, it would be prudent to assume the re-engineered cover system is not acting as a typical 'capping layer' i.e. is not impermeable and is not aiding in significant reduction of rainfall infiltration.

Generally, the Delta-Simons findings correlate with the depth and geological descriptions provided within the WYG Geo-Environmental Investigation Report. WYG noted the re-engineered cover system did comprise a clay material with subordinate amounts of sand and gravel – again indicating the re-engineered cover system is not uniformly cohesive.

The landfill waste within the east cell appeared to consist of more 'household waste' items including plastic containers, kitchen waste, glass bottles, newspapers and books. The near surface waste (encountered within the trial pits up to 4 m bgl), appeared to have undergone very little degradation, evidenced by the recovery of in-tact newspapers and books. Delta-Simons recovered newspapers dated 1986 and WYG recorded a letter

dated 1982. Throughout the waste mass, the percentage and composition of the matrix varied. A proven depth to base of the landfill waste plan is included as Figure 2.

The cross section below (Diagram 1), for the east cell, demonstrates the varying thickness of the cover material and superficial deposits. The cross section also highlights the potential original re-engineered cover system materials situated within the waste. This may be associated with the brief termination of landfill waste disposal and provision of a 'cover system' followed by further waste disposal.

Diagram 1 – Cross Section of East Cell



4.2.2 West Cell

A summary of the observed ground conditions at the Site is provided below.

Summary of Observed Ground Conditions				
Strata	**Typical Strata Description**	**Depth Range of Strata Base (m)**	**Maximum Proven Thickness (m)**	**Comments**
Made Ground: Topsoil	Soft slightly sandy slightly gravelly CLAY.	*0.19 (TP104) – 0.8 (RO101)*	*0.8 (RO101)*	*Encountered in all locations except RO108.* *Topsoil generally appears to be the thinnest in the central area of the Site and thickest in the west.* *Composition similar across the west cell.*
Made Ground: Re-engineered cover system (Granular)	Gravelly clayey SAND. Gravel of sandstone, flint, brick and concrete.	*0.5 (RO108) – 2.0 (RO103)*	*1.71 (TP104)*	*Encountered in three locations, at varying depths, across the west cell.* *RO108 (south-east of west cell) was encountered at the surface.*
Made Ground: Re-engineered cover system (Cohesive)	Firm to stiff slightly gravelly sandy CLAY. Gravel of Chalk, flint, and brick. Friable gravelly SILT. Gravel of Chalk, flint and rare clinker.	*0.6 (TP102) – 3.5 (RO107)*	*3.2 (RO107)*	*Encountered in ten locations across the west cell with varying proven thickness.* *The cohesive capping layer was more prevalent than the granular capping layer within the west cell.* *Silt encountered in only five locations across the west cell – predominantly clay.*
Made Ground: Suspected Original Re-engineered cover system	Soft slightly sandy CLAY.	*2.14 (RO101) – 506 (RO107)*	*0.2 (RO107)*	*Encountered in four locations across the west cell.* *Generally thinner than what was encountered in the east cell.* *Also encountered underlying and overlying the landfill waste and identifiable by a complete lack of waste debris.*
Made Ground: Landfill Waste	Landfill recovered as frequent plastic, fabric and cable fragments with approximately 80% matrix of black slightly gravelly clayey SAND. Gravel is of flint. Landfill recovered as frequent wood, plastic, metal, occasional tyres, sponge, brick, textile, glass, clinker, rare steel and carpet with approximately 40% matrix of very soft dark brown slightly sandy CLAY.	*8.9 (RO102) – 10.7 (RO101)*	*8.56 (RO101)*	*Encountered in every exploratory location.* *The waste thickness was thinner than the east cell – which accounts for the significant elevation difference.* *Significantly less modern 'household' waste than the east cell i.e. less plastic household waste, paper and newspapers.* *Composition highly variable across the cell – particularly percentage of matrix. The percentage of matrix (non-waste, soil material) ranged from 10 to 100%.*

Made Ground: Reworked River Terrace Deposits	Light brown very clayey GRAVEL of flint with occasional wood and plastic fragments.	*9.5 (RO108) – 10 (RO103)*	*0.9 (RO103)*	*Encountered in two locations in the centre and south-east of the west cell.*
River Terrace Deposits	Yellowish brown slightly sandy slightly clayey GRAVEL of flint.	*11.1 (RO108) – 12.2 (RO103)*	*3.3 (RO102)*	*Encountered in three locations situated in the east and centre of the west cell.* *Thickness of strata ranges from 1.6 – 3.3 m with thinnest encountered in the south-east of the west cell.*
Alluvium	Soft brown slightly gravelly SILT. Gravel of Chalk. Very soft brown mottled grey silty CLAY.	*11.1 (RO101) – 12.2 (RO107)*	*2.6 (RO107)*	*Encountered two locations in the north-west and south-west of the west cell. The strata was very limited in the north-west with a thickness of 0.4 m.*
Lewes Nodular Chalk Formation (Grade Dc)	Structureless CHALK composed of silty GRAVEL. Clasts are very weak low density white of Chalk.	*Base not proven.*		*All Chalk encountered was recorded as structureless with interbedded cohesive and granular stratums.* *SPTs were variable but generally increased with depth.*
Lewes Nodular Chalk Formation (Grade Dm)	Structureless CHALK composed of greyish white slightly gravelly SILT. Gravel is very weak low density white Chalk and flint.			

Similar to the east cell, the west cell also has varying thicknesses of re-engineered cover system material, landfill waste and superficial deposits (see Diagram 2 below).

Diagram 2 – Cross Section of West Cell



The landfill waste in this cell comprised less common household items and notably more 'industrial' items including large tyres, wood, metal and large-scale deposits of metal baby-powder containers. No 'black bag' waste or in-tact newspapers etc. were encountered within the west cell. However, residential waste streams in the early to mid-1970s would have contained a higher proportion of ashes & cinders. Ash was identified in the landfill waste within the west cell however, the ash content was notable greater and more widespread in the east. The west cell is also lower topographically, with regard to the east cell, which, along with the differences in waste types, supports the idea of two separate waste cells with differing dates of deposition.

WYG encountered a newspaper dated 1976, suggesting the west cell was active during the 1970s and the east cell was filled until the 1980s.

Alluvium was encountered in the western half of the Site (not encountered within the eastern half). The Delta-Simons and WYG investigations both recorded alluvium in two locations, generally in the same areas of the Site. This indicates the predominant superficial deposit across the Site comprises granular River Terrace Deposits with very limited alluvium.

When compared to the re-engineered cover system in the eastern half of the Site, the western half appears to comprise more cohesive material, with less locations encountering granular based material (illustrated in Figure 5). However, the cohesive material still recorded granular secondary constituents that will likely act to decrease the overall permeability of the material.

Both Delta-Simons and WYG investigations recorded structureless, very weak Chalk across the Site.

4.3 Visual and Olfactory Evidence of Contamination - Soils

Visual and olfactory evidence of potential contamination was observed during the Delta-Simons and WYG investigation, the findings are summarised in the table below.

Exploratory Location	Depth (m bgl)	Strata	Notes
Delta-Simons			
RO101	3.0 – 7.0	Landfill waste	Moderate hydrocarbon odour
RO102	2.2 – 2.5	Landfill Waste	Moderate hydrocarbon odour.
	2.5 – 3.0		Slight hydrocarbon odour.
RO103	3.0 – 3.2	Landfill Waste	Strong hydrocarbon odour.
	3.0 – 3.1	Landfill Waste	Slight hydrocarbon sheen.
	3.2 – 3.9	Landfill Waste	Moderate hydrocarbon odour.
	13.0 – 13.5	Chalk	Slight hydrocarbon odour.
	13.5 – 14.2	Chalk	Moderate hydrocarbon odour.
RO104	5.0 –7.0	Landfill Waste	Moderate hydrocarbon odour and a moderate sheen. Becomes a slight odour with no sheen from 6.0 m bgl.
RO105	6.0 – 10.4	Landfill Waste	Moderate hydrocarbon odour. Becomes slight from 7.0 m bgl.
RO106	1.5 – 4.0	Landfill Waste	Slight hydrocarbon odour.
RO106	11.0 – 11.5	Landfill Waste	Strong sweet solvent odour.

RO108	3.8 – 4.0	Landfill Waste	Slight creosote odour associated with a railway sleeper.
RO109	4.0 – 6.0	Landfill Waste	Strong waste odour.
TP101	2.25 – 3.75	Landfill Waste	Strong waste odour.
TP102	1.5 – 3.6	Landfill Waste	Slight hydrocarbon odour.
TP104	1.9 – 3.6	Landfill Waste	Strong waste odour.
TP108	1.4 – 4.0	Landfill Waste	Moderate solvent odour.
TP109	0.9 – 3.9	Landfill Waste	Strong solvent odour.
TP110	3.6 – 6.7	Landfill Waste	Slight hydrocarbon odour.
TP113	2.0 – 3.85	Landfill Waste	Slight solvent odour.
TP114	0.85 – 3.9	Landfill Waste	Strong waste odour.
TP115	3.1 – 3.6	Landfill Waste	Strong waste odour.
TP117	2.4 – 3.9		
WYG			
CP01	3.0 – 10.3	Landfill Waste	Slight rotten odour.
CP06	2.5 – 9.3	Landfill Waste	Foul / rotten odour.
TP01	1.3 – 3.4	Landfill Waste	Slight rotten odour.
TP03	2.1 – 3.4	Landfill Waste	Moderate rotten odour.
TP04	3.0 – 3.3	Landfill Waste	Rotten odour.
TP05	1.4 – 3.1	Landfill Waste	Ashy / burnt odour.
TP06	0.9 – 3.1	Landfill Waste	Foul / rotten odour.
TP07	2.7 – 3.3	Landfill Waste	Rotten odour.
TP08	1.0 – 3.2	Landfill Waste	Slight rotten odour.
TP11	1.5 – 3.0	Landfill Waste	Moderate rotten odour.

4.4 Groundwater

4.4.1 Strikes During Investigations

Groundwater strikes recorded as excavation progressed during the Delta-Simons investigation range from 1.0 to 17.0 m bgl (9.04 to -6.61 m AOD). The groundwater strikes during the investigation are summarised below.

Delta-Simons				
Exploratory Hole	**Water strike during drilling (m bgl)**	**Water strike during drilling (m AOD)**	**Stratum**	**Comment**
RO101	11.5	-0.47	Chalk	Medium inflow rate.
RO102	1.0	9.04	Re-engineered Cover System	Slow inflow rate.
RO102	9.0	1.04	River Terrace Deposits	Medium inflow rate.
RO103	7.6	2.85	Landfill Waste	Medium inflow rate.
RO105	2.5	7.89	Landfill Waste	Fast inflow rate.
RO105	17.0	-6.61	Chalk	Fast inflow rate.
TP104	1.8	8.19	Landfill Waste	Fast ingress.
TP112	3.5	5.44	Landfill Waste	
TP117	2.4	7.91	Landfill Waste	Fast ingress.
TP119	2.75	6.63	Landfill Waste.	

Groundwater strikes recorded as excavation progressed during the WYG investigation ranged from 3.9 to 11.5 m bgl (4.27 to -0.96 m AOD). The groundwater strikes during the investigation are summarised below.

WYG				
Exploratory Hole	**Water strike during drilling (m bgl)**	**Water strike during drilling (m AOD)**	**Stratum**	**Comment**
CP01	11.5	-0.96	River Terrace Deposits	-
CP02A	9.6	1.19	Alluvium	-
CP03	10.5	-1.83	River Terrace Deposits	-
CP04	6.3	5.22	Landfill Waste	-
CP05	5.9	3.66	Landfill Waste	-
CP06	4.3	8.1	Landfill Waste	-
TP09	3.9	4.27	Landfill Waste	-

4.4.2 Levels During Monitoring Programme

Groundwater levels were monitored on a total of four occasions between 22nd March and 20th May 2021. Monitoring data is included within the Delta-Simons Factual Site Investigation Report (reference: 19-2099.04) and summarised in the table below.

As part of the Delta-Simons investigation, three of the WYG boreholes (CP02A, CP03 and CP05) were appropriately developed and monitored alongside the Delta-Simons newly installed boreholes. The results of the additional monitoring on the WYG boreholes as part of Delta-Simons' scope of works is also included in the summary below.

Delta-Simons										
Exploratory Hole	**Response Zone**				**Water level during monitoring Max to Min Range**				**LNAPL Y/N**	**Stratum**
	m bgl		**m AOD**		**m bgl**		**m AOD.**			
RO101 (S)	1.50	10.50	9.53	0.53	7.93	8.25	2.78	3.10	N	Landfill Waste
RO101 (D)	16.00	23.00	-4.97	-11.97	7.57	8.15	1.89	2.47	N	Chalk
RO102 (S)	3.00	8.00	7.04	2.04	7.25	7.95	2.50	3.20	N	Landfill Waste
RO102 (D)	16.00	22.00	-5.96	-11.96	8.38	8.40	2.48	2.50	N	Chalk
RO103 (S)	3.00	9.00	7.45	1.45	2.54	8.50	1.89	7.85	N	Landfill Waste
RO103 (D)	16.00	23.00	-5.55	-12.55	10.54	11.05	1.63	2.14	N	Chalk
RO104 (S)	1.50	10.00	9.38	0.88	8.78	9.92	1.11	2.25	N	Landfill Waste
RO104 (D)	16.00	22.00	-5.12	-11.12	8.42	8.61	1.43	1.62	N	Chalk
RO105 (S)	2.00	10.50	8.39	-0.11	8.72	9.69	0.76	1.73	N	Landfill Waste
RO105 (D)	16.00	21.00	-5.61	-10.61	9.32	9.63	1.25	1.56	N	Chalk
RO106 (S)	2.00	13.50	10.68	-0.82	8.72	9.70	0.69	1.67	N	Landfill Waste
RO106 (D)	16.00	22.00	-3.32	-9.32	11.19	11.56	1.12	1.49	N	Chalk
RO107	14.00	20.00	-3.26	-9.26	9.57	9.72	1.02	1.17	N	Chalk
RO108	12.00	20.00	-3.01	-11.01	7.43	7.94	1.06	1.57	N	Chalk
RO109	16.00	20.00	-6.21	-10.21	8.71	8.84	0.95	1.08	N	Chalk
DS101	9.50	10.50	-0.08	-1.08	8.36	8.84	0.58	1.06	N	River Terrace Deposits
DS102	10.50	12.50	0.35	-1.65	9.25	9.73	1.12	1.60	N	River Terrace Deposits
DS103	10.50	12.50	-0.58	-2.58	8.10	9.10	0.82	1.82	N	River Terrace Deposits
CP02A (S)	1.00	9.00	9.79	1.79	7.98	8.79	2.00	2.81	N	Landfill Waste
CP02A (D)	13.0	35.0	-2.21	-24.21	9.25	9.54	1.25	1.54	N	Chalk
CP03 (S)	1.00	10.0	7.67	-1.33	5.19	7.34	1.33	3.48	N	Landfill Waste
CP03 (D)	14.0	35.0	-5.33	-26.33	7.24	7.49	1.18	1.43	N	Chalk
CP05 (S)	1.00	10.0	8.56	-0.44	6.72	7.63	1.93	2.84	N	Landfill Waste
(S) = Monitoring standpipe installed within a shallower stratum as part of a dual install (D) = Monitoring standpipe installed within a deeper stratum as part of a dual install										

Groundwater levels were monitored by WYG on a total of six occasions between 22nd March and 20th May 2021. Monitoring data and LNAPL measurements are summarised in the table below.

WYG										
Exploratory Hole	**Response Zone**				**Water level during monitoring Max to Min Range**				**LNAPL Y/N**	**Stratum**
	m bgl		**m AOD**		**m bgl**		**m AOD.**			
CP01 (D)	14.0	35.0	-3.46	-24.46	8.56	9.29	1.25	1.98	NR	Chalk
CP01 (S)	1.0	11.0	9.54	-0.46	7.67	8.02	2.52	2.87	NR	Landfill Waste

WYG										
Exploratory Hole	Response Zone				Water level during monitoring Max to Min Range				LNAPL Y/N	Stratum
	m bgl		m AOD		m bgl		m AOD.			
CP02A (D)	13.00	35.00	-2.21	-24.21	8.875	10.8	-0.01	1.915	NR	Chalk
CP02A (S)	1.00	9.00	9.79	1.79	7.95	9.07	1.72	2.84	NR	Landfill Waste
CP03 (D)	14.00	35.00	-5.33	-26.33	6.6	8.69	-0.02	2.07	NR	Chalk
CP03 (S)	1.00	10.00	7.67	-1.33	6.71	7.72	0.95	1.96	NR	Landfill Waste
CP04	1.0	9.0	10.52	2.52	7.01	8.52	3.0	4.51	NR	Landfill Waste
CP05	1.00	10.00	8.56	-0.44	6.84	7.27	2.29	2.72	NR	Landfill Waste
CP06	1.0	9.0	11.4	3.4	7.13	7.67	4.73	5.27	NR	Landfill Waste
WS01	1.0	2.7	9.28	7.58	2.66	Dry	Dry	7.63	NR	Re-engineered Cover System
WS02	1.0	5.0	9.57	5.57	Dry	Dry	Dry	Dry	NR	Re-engineered Cover System
WS03	1.0	3.0	10.07	8.07	Dry	Dry	Dry	Dry	NR	Re-engineered Cover System
WS04	1.0	4.0	10.01	7.01	Dry	Dry	Dry	Dry	NR	Re-engineered Cover System
WS05	1.0	3.0	9.72	7.72	Dry	Dry	Dry	Dry	NR	Landfill Waste
WS06	1.0	5.0	9.98	5.98	5.68	Dry	Dry	5.3	NR	Re-engineered Cover System
WS07	1.0	3.0	9.12	7.12	Dry	Dry	Dry	Dry	NR	Re-engineered Cover System
WS08	1.0	3.5	13.21	10.71	Dry	Dry	Dry	Dry	NR	Re-engineered Cover System
WS09	1.0	4.0	8.46	5.46	4.57	Dry	Dry	4.89	NR	Landfill Waste
WS10	1.0	4.0	12.45	9.45	4.32	Dry	Dry	9.13	NR	Landfill Waste
(S) = Monitoring standpipe installed within a shallower stratum as part of a dual install (D) = Monitoring standpipe installed within a deeper stratum as part of a dual install NR = Not Recorded										

4.4.3 LevelLogger™ Data

The Levelogger™ is a datalogger which measures the groundwater level (or surface water levels) and water temperature. Water levels are displayed as temperature compensated pressure readings and are barometrically compensated with the aid of a Barologger™. The Barologger uses algorithms based on air pressure only. It measures and logs changes in atmospheric pressure, which are then used to compensate water level readings recorded by a Levelogger™.

The table below summarises the Levelogger™ data, with the minimum and maximum groundwater depth for each borehole included. The data allows for assessment of tidal impact on the groundwater across the Site and enables comparison both laterally across the Site and within different lithologies.

Location	Minimum Depth to Groundwater (m AOD)	Maximum Depth to Groundwater (m AOD)	Average Tidal Range (m)
DS101	1.835	0.725	0.9

DS103	1.009	0.657	0.1
RO101	1.935	0.343	1.0
RO105	2.473	1.031	1.3
RO108	2.207	0.728	1.3
RO109	2.129	0.528	1.5

The continuous groundwater monitoring indicates the groundwater within the Chalk wells is strongly tidally influenced. The vertical tidal fluctuation within boreholes installed within the Chalk was typically between 1.0m and 1.3 m through each tidal cycle (depending on the strength of the tide). This tidal influence was similar within both RO105 (circa 50 m to open water) and RO101 (>300 m from open water). This indicates that the tidal influence extends across the entire Site and results in rapid and relatively consistent rises and falls every 12 hours.

The data for the two wells installed within the RTD indicates variable responses to tidal influence. DS101 has a vertical range of up to circa 0.9m indicating that this well is in close or direct connectivity with the main groundwater table with limited or no separation. DS103 however has a maximum tidal variation of circa 0.1m, which suggests hydraulic separation caused by a low permeability stratum. The limited tidal influence could potentially be due to lateral inflow of tidal water from the Hermitage Stream to the east, rather than from the wider estuary, with rising groundwater from the underlying Chalk locally impeded.

The RTD data indicates the locally complex hydrogeological regime. Typically, the upper weathered surface of the Chalk weathers to a low permeability clay consistency with fissures and fractures absent, (often referred to as Putty Chalk) and this can act as a hydraulic seal. However, in this coastal locality, the historical tidal creeks are likely to have eroded this low permeability Putty Chalk in some areas and not in others. Hence, locally there will be evidence of multiple perched water bodies within the RTD (and / or the Made Ground above) although there is no continuous / consistent perched groundwater body and across the wider Site area there is likely to be good hydraulic connectivity.

The Levelogger™ data recorded within the Chalk wells all indicated significant tidal influence. When comparing the data against high and low tide within the adjacent Langstone Harbour, it is evident that as the tide rises, groundwater levels increase across the Site with a direct correlation and only a short time lag. Groundwater elevation data taken during an ebbing tide indicates a southerly / south-easterly flow direction in the west of the Site with a more easterly flow direction in the east of the Site, close to the Hermitage Stream. This is illustrated on the groundwater contour plan included as Figure 6. It is expected that this flow direction will reverse twice daily – elevation monitoring data taken during a rising tide is inconsistent and does not indicate a specific flow direction, but this is expected given the local variations in strata permeability and associated response to the incoming tide.

The data graphs for each monitoring wells are included within the Delta-Simons Factual Geo-Environmental Investigation Report (reference: 19-2099.04).

4.4.4 Water Infiltration in the Landfill Waste

The cross section overleaf summarises the groundwater data (water strikes) identified during the Delta-Simons intrusive investigation (represented as black triangles) and during the groundwater monitoring programme (coloured triangles based on targeted strata). The cross section demonstrates that groundwater is present within the landfill waste and the Chalk – at somewhat similar levels. However, for the most part, the groundwater within the landfill waste is marginally but distinctly above the groundwater within the Chalk.

Perched water encountered during the intrusive investigation by Delta-Simons is presented on the cross section below. Generally, it appears that perched water is more prevalent within the landfill waste in the west cell. This correlates with the ground model discussion regarding the higher content of granular material within the re-engineered cover system in the east cell.

The presence of perched water, particularly within isolated locations within the waste, would indicate preferential degradation of waste materials in these areas. This is likely to translate to waste that is more degraded in more saturated zones as opposed to drier areas where degradation will be slower. This can impact the ground gas

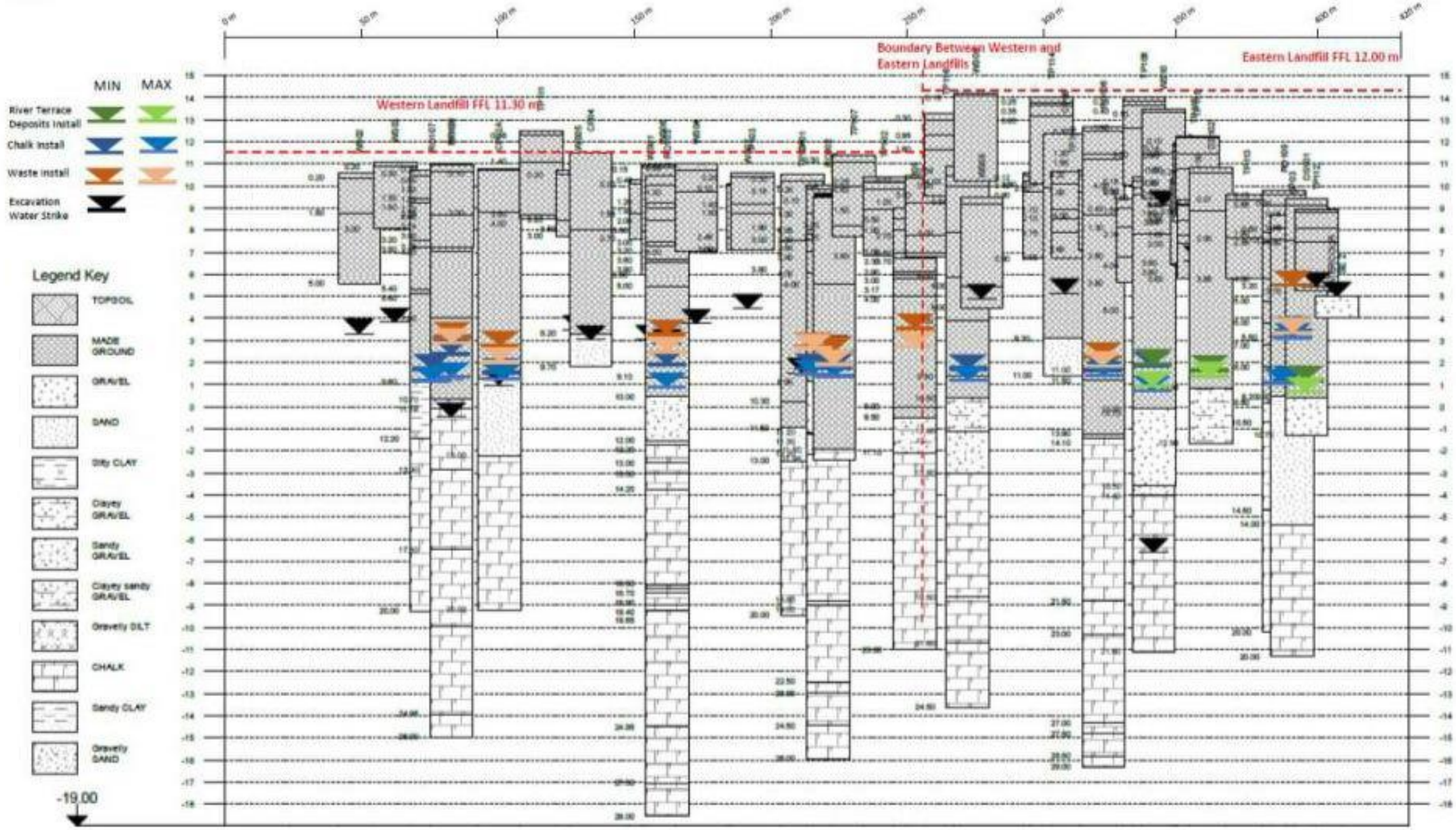
generation across the Site as well as contribute to the general heterogeneity of the landfill waste across the Site.

The monitoring data provides evidence of limited and inconsistent perching of water on the weathered surface of the Chalk and lenses within the waste mass. Overall, there is evidence of a high degree of vertical hydraulic connectivity, suggesting infiltration of rainwater can proceed vertically to the Chalk aquifer with only limited infiltration attenuation afforded by areas of intact 'Putty' Chalk and some cohesive lenses within the overlying waste mass.

W

Diagram 3 – Cross Section of Site with Depth to Groundwater

E



4.5 Visual and Olfactory Evidence of Contamination - Groundwater

Visual and olfactory evidence of potential gross contamination was observed during the Delta-Simons and WYG investigations, the findings are summarised in the table below.

Exploratory Hole	Stratum	Comments
Delta-Simons		
TP117	Landfill Waste	Slight sheen on groundwater during excavation.
WYG		
CP02	Landfill Waste	Slight sheen and landfill type odour during low flow groundwater monitoring.
CP03	Landfill Waste	Slight sheen during groundwater purging and sampling.
CP04	Landfill Waste	Slight sheen and ammonia type odour during low flow groundwater monitoring.
CP06	Landfill Waste	Slight sheen during low flow groundwater monitoring.

4.6 Low-Flow Water Quality Data

Delta-Simons undertook water quality data testing on one occasion using a multiparameter water monitoring probe. This comprised the collection of one water sample for analysis with the multiparameter probe to assess the steady state dissolved oxygen content within the groundwater. The results are summarised in the table below.

WYG undertook groundwater sampling with a low flow sampling kit on one occasion, the final water quality parameters are also summarised below.

Exploratory Location	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen Concentration (mg/L)	Oxidation Reduction Potential (mV)
Delta-Simons					
RO101	6.88	12.9	3,750.3	5.97	-33.5
RO106	7.36	12.94	2,313.3	3.06	76.5
RO107	7.26	12.85	3,987.6	6.50	23.3
RO109	7.32	12.81	1,301.3	4.23	28.9
WYG					
CP01 (D)	7.02	11.7	531	8.18	22.5
CP01 (S)	6.86	13.1	6,079	0.25	-117.6
CP02A (D)	6.69	12.2	3,251	0.59	-93.1
CP02A (S)	6.65	15.10	3,172	0.94	-88.3
CP03 (S)	6.9	12.3	523	2.55	5.8

Exploratory Location	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen Concentration (mg/L)	Oxidation Reduction Potential (mV)
CP03 (S)	6.62	12.8	1,259	0.26	-84.2
CP04	6.75	12.9	4,792	0.22	-155
CP05	6.77	12.9	2,656	1.29	-90.8
CP06	6.77	12.7	2,281	0.31	-102.5

4.7 Material Properties

The tables below summarise the factual material properties based upon the results of in-situ and laboratory test data and where appropriate provides derived geotechnical parameters. The material properties have been divided as per the ground summary above, split into east landfill cell and west landfill cell respectively.

Where relevant, data from the previous third-party WYG investigation has also been summarised in blue. Due to discrepancy in the data, SPT N values from the WYG investigation have not been included. Notes applicable for both east and west summary tables are included below in section 4.7.2.

For further information, the CPT results and borehole and trial pit logs have been included within the Delta-Simons Factual Site Investigation Report (19-2099.04).

4.7.1 East Cell

Parameter	Unit	Value/Range	Justification
Made Ground- Topsoil			
w (Moisture Content)	%	15	Laboratory Testing
Made Ground- Re-Engineered Cover System (Granular)			
w (Moisture Content)	%	17	Laboratory Testing
IP (Plasticity Index)	-	20	
IP' (Modified Plasticity Index)	-	11	
PL (Plastic Limit)	%	24	
LL (Liquid Limit)	%	44	
S_u (Derived Undrained Shear Strength)3	kPa	75 – 300	CPT Report
Made Ground – Re-Engineered Cover System (Cohesive)			
w (Moisture Content)	%	10 – 26	Laboratory Testing
w' (As Received Moisture Content)	%	19 – 26	
γd (Dry Density)	Mg/m^3	1.60 – 1.86	
Optimal Moisture Content (OMC)	%	15 – 19	
Maximum Dry Density (MDD)	Mg/m^3	1.71 – 1.86	
Moisture Condition Value (MCV)	-	6.4 – 10.8	
Uncorrected SPT 'N'	Blows	15 – 50	In Situ Testing
Corrected SPT 'N_{60}'	-	13 – 43	Er=51%
S_u (Derived Undrained Shear Strength)	KPa	40 – 150	CPT Report
Cu (Undrained Shear Strength)	KPa	58	Laboratory Testing
c' (Drained Shear Strength)	KPa	0	Conservative long-term parameter often utilised in slope design.
ϕ' (Drained Angle of Shearing Resistance)	Degrees	27	Derived from maximum PI of 25 in west cell.
Made Ground – Landfill Waste			
Uncorrected SPT 'N'	Blows	16 – 50	In Situ Testing
Corrected SPT 'N_{60}'	-	14 – 43	Er=51%
River Terrace Deposits			
Uncorrected SPT 'N'	Blows	14 – 42	In Situ Testing
Corrected SPT 'N_{60}'	-	12 – 36	Er=51%
ϕ' (Drained Angle of Shearing Resistance)	Degrees	31 – 38	Derived from corrected N_{60} values and CPT data.
Lewes Nodular Chalk Formation – Grade Dc			
Uncorrected SPT 'N'	Blows	7 – 14	In Situ Testing
Corrected SPT 'N_{60}'	-	6 – 12	Er=51%
Lewes Nodular Chalk Formation – Grade Dm			
WC (Water Content)	%	24	Laboratory Testing
IS(50) (Point Load Strength Index)	MPa	0.16	
Uncorrected SPT 'N'	Blows	6 – 50	In Situ Testing
Corrected SPT 'N_{60}'	-	5 – 43	Er=51%

4.7.2 West Cell

Parameter	Unit	Value/Range	Justification
Made Ground – Re-Engineered Cover System (Cohesive)			
w (Moisture Content)	%	16 – 28	Laboratory Testing
w' (As Received Moisture Content)	%	11 – 26	
IP (Plasticity Index)	-	15 – 25	
IP' (Modified Plasticity Index)	-	9 – 18	
PL (Plastic Limit)	%	19 – 21	
LL (Liquid Limit)	%	36 – 44	
γd (Dry Density)	Mg/m^3	1.56 – 1.79	
Optimal Moisture Content (OMC)	%	16 – 22	
Maximum Dry Density (MDD)	Mg/m^3	1.66 – 1.79	
Moisture Condition Value (MCV)	-	9.6	
Uncorrected SPT 'N'	Blows	5 – 16	In Situ Testing
Corrected SPT 'N_{60}'	-	4 – 14	Er=51%
S_u (Derived Undrained Shear Strength)	KPa	20 – 300	CPT Report
c' (Drained Shear Strength)	KPa	0	Conservative long-term parameter often utilised in slope design.
ϕ' (Drained Angle of Shearing Resistance)	Degrees	27	Derived from maximum PI of 25.
Made Ground Suspected Original Re-Engineered Cover System			
w (Moisture Content)	%	9 – 29	Laboratory Testing
Uncorrected SPT 'N'	Blows	11	In Situ Testing
Corrected SPT 'N_{60}'	-	9	Er=51%
S_u (Derived Undrained Shear Strength)	KPa	20 – 150	CPT Report
Cu (Undrained Shear Strength)	KPa	63	Laboratory Testing
Made Ground – Landfill Waste			
Uncorrected SPT 'N'	Blows	50	In Situ Testing
Corrected SPT 'N_{60}'	-	43	Er=51%
Alluvium			
w (Moisture Content)	%	24 22 – 48	Laboratory Testing
IP (Plasticity Index)	-	9 – 50	
IP' (Modified Plasticity Index)	-	8 – 45	
PL (Plastic Limit)	%	17 – 38	
LL (Liquid Limit)	%	26 – 88	
C_u (Undrained Shear Strength)	KPa	29	
S_u (Derived Undrained Shear Strength)	KPa	40 – 150	CPT Report
Lewes Nodular Chalk Formation – Grade Dc			
w (Moisture Content)	%	14	Laboratory Testing
IP (Plasticity Index)	-	11	
IP' (Modified Plasticity Index)	-	9	
PL (Plastic Limit)	%	17	
LL (Liquid Limit)	%	28	
γd (Dry Density)	Mg/m^3	1.12	
γ (Bulk Density)	Mg/m^3	1.66	
WC (Water Content)	%	21.7 – 26	
IS(50) (Point Load Strength Index)	MPa	0.03 – 0.24	

Uncorrected SPT 'N'	Blows	19 – 50	In Situ Testing
Corrected SPT 'N_{60}'	-	16 – 43	Er=51%
Lewes Nodular Chalk Formation – Grade Dm			
WC (Water Content)	%	14.7	Laboratory Testing
Saturated Moisture Content (SMC)	%	25	
IS(50) (Point Load Strength Index)	MPa	0.06	
γd (Dry Density)	Mg/m^3	1.61	
γ (Bulk Density)	Mg/m^3	1.83 – 2.09	
Uncorrected SPT 'N'	Blows	11 – 50	In Situ Testing
Corrected SPT 'N_{60}'	-	9 – 43	Er=51%
Permeability (k)[5]	m/sec	1.2E-09 – 3.4E-10	Laboratory Testing

Notes:

1. SPT N values corrected for energy delivered to drive rods utilising the determined energy ratio (Er): N60 = (Er x N)/60 after BS EN ISO 22476-3:2005 [Ref. 5]
2. Modified Plasticity Index values generated from the equation *IP' = (IP x ($\%_{425um}$)/100*. Where ($\%_{425um}$) is the percentage of the sample passing through a 425um sieve.
3. Derived undrained shear strength *(S_u)* ranges have been determined based upon strength classifiers from the third-party CPT data.
4. Angle of internal friction has been derived in granular soils from in-situ standard penetration testing and inferred N values from CPT data.
5. Based on Triaxial Permeability Testing undertaken within the laboratory

4.7.3 Earthworks Material Classification

Earthwork's testing has been undertaken as part of this assessment. The table below summarises material grading results and the corresponding earthworks class, in accordance with the Specification for Highways Works, Series 600, Table 6/2:

Exploratory Location	Depth (m bgl)	Strata	Cobble Content (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)		Series 600 Earthworks Class (Table 6/2)
						Silt	Clay	
TP101	1.00	Made Ground Re-Engineered Cover System (West)	0	10	21	43	26	Class 2A/2B
TP102	0.30		0	1	21	44	34	
TP104	0.50		8	59	17	16		Class 2C
TP106	0.50		31	33	14	21		
TP109	0.50	Made Ground Re-Engineered Cover System (East)	0	17	50	33		Class 2A/2B
TP110	0.50		0	22	67	11		Class 1A/1B
TP111	0.50		0	6	23	43	28	Class 2A/2B
	3.80		0	1	9	67	23	
TP112	0.9		0	25	29	33	13	Class 2C
TP113	1.00		0	36	21	43		
TP115	0.20		0	13	69	18		Class 2A/2B

4.8 Geochemical Testing

Geochemical analysis was undertaken on soil samples of Made Ground (including cover system and landfill mass, Alluvium, River Terrace Deposits, and Lewes Nodular Chalk Formation). These were tested for selective

contaminants as detailed in (BRE Special Digest 1:2005 (3rd Edition), Concrete in Aggressive Ground. The results are summarised in the table below.

Tests	No. of Tests	Minimum	Maximum
Soil - pH	74	7.0	9.5
Soil - Total Sulphur	39	0.01%	1.08%
Soil – Acid Soluble Sulphate	38	0.019%	0.255%
Soil - Water Soluble Sulphate	69	0.012 g/l	4.2 g/l
Water – pH	64	6.7	7.4
Water - Sulphate	64	3.94 mg/L	631 mg/L

4.9 Forensic Waste Testing

Forensic waste analysis was undertaken on ten bulk samples of landfill waste, as part of the Delta-Simons investigation, to determine the percentage of putrescible material and total organic content (TOC). The results are summarised in the table below.

Exploratory Hole	Depth (m bgl)		% of Putrescible Material	TOC %	Loss on Ignition (%)	Landfill Cell
	From	To				
TP101	2.5	3	3.3	2.5	4.5	East
TP102	1.7	2	7.1	3.9	NT	East
TP104	3.5	3.8	19.6	1.6	NT	East
TP106	3	3.5	2.1	4	6.1	East
TP107	3.5	3.7	0	0.8	NT	West
TP109	3	3.5	6	2.7	NT	West
TP111	2	2.5	8.2	1.8	3.9	West
TP112	1.7	2	9.2	1.8	NT	West
TP114	1	1.5	10.5	5.5	NT	West
TP117	2	2.5	3.7	1.9	4.9	West
RO104	20	20.45	NT	0.3	NT	East
RO105	17	17.45	NT	0.1	8.1	East
RO106	26	26.45	NT	0.1	10.4	East
RO109	12	13	NT	0.2	NT	West
NT: Not Tested						

Each sample was segregated into 12 constituents and the proportions calculated as a percentage. The constituents considered to represent 'putrescible material' include wood, trees, branches, green vegetables, cloth, leather, paper, card and other degradable material.

The percentage of putrescible material within the landfill waste in the east cell ranged between 2.1 to 19.6 % and 0 to 10.5% in the west. This is generally in line with the conditions outlined in the ground summary and the observations made between the differing waste cells.

4.10 Ground Gas Data

Gas monitoring comprised conventional spot monitoring and the deployment of continuous monitoring instruments for a total period of approximately eight weeks. Gas monitoring results from all data sets are presented in the Delta-Simons Factual Geo-Environmental Investigation Report (reference: 19-2099.04) and are also summarised in the tables below.

4.10.1 Bulk Gases & Flow Rates

A total of four ground gas monitoring rounds have been undertaken by Delta-Simons over a period of eight weeks (from March to May 2021).

Ground Gas Solution (GGS) also undertook spot monitoring on two occasions as part of the continuous monitoring programme. RO101 to RO106 (installed within the landfill waste), were monitored from March to April 2021. The results have been included in the summary below.

WYG also undertook six rounds of ground gas monitoring (from 18th May to 27th June 2017), the results of which are also summarised below.

Exploratory Hole	Steady Gas Concentration (%v/v)						Steady Flow Rate (l/hr)		Response Zone (m bgl)		Stratum	Flooded?
	Methane		Carbon Dioxide		Oxygen							
	Min	Max	Min	Max	Min	Max	Min	Max	From	To		
Delta-Simons												
RO101 (S)	37.1	65	20.4	25.5	<0.1	0.3	<0.1	3.1	1.5	10.5	Landfill	0 of 5
RO102 (S)	57.6	62.8	15.5	25.1	<0.1	1.8	<0.1	0.4	3	8	Landfill	0 of 5
RO103 (S)	58.4	67.4	21.3	28	<0.1	0.2	<0.1	0.7	3	9	Landfill	0 of 5
RO104 (S)	14.3	36	9.4	22.2	<0.1	2.4	<0.1	0.1	1.5	10	Landfill	0 of 5
RO105 (S)	<0.1	20.9	0.7	13.2	2.5	19.3	<0.1	-0.2	2	10.5	Landfill	0 of 5
RO106 (S)	28.5	53.7	14.4	24.6	<0.1	0.3	<0.1	3.5	2	13.5	Landfill	0 of 5
RO107 (D)	19.2	35	9.3	17.9	0.7	10.3	<0.1	0.3	14	20	Chalk	4 of 4
RO108 (D)	<0.1	<0.1	<0.1	0.1	20.5	21.2	<0.1	-0.1	12	20	Chalk	4 of 4
RO109 (D)	<0.1	1.3	0.1	0.5	20.1	20.5	<0.1	-0.9	16	20	Chalk	4 of 4
DS101	<0.1	2.8	0.1	2.1	15.8	20.3	<0.1	<0.1	9.50	10.50	Superficial	0 of 4
DS102	0.2	32.2	0.1	0.4	2.1	21.1	<0.1	<0.1	10.50	12.50	Superficial	0 of 4
DS103	0.2	17.4	0.7	9.3	9.3	20.2	<0.1	<0.1	10.50	12.50	Superficial	0 of 4
CP02A (S)	0.1	6	0.8	8.3	12.8	19.8	<0.1	-0.1	1	9	Landfill	0 of 4
CP02A (D)	<0.1	15.3	0.9	15.3	7.5	20.5	<0.1	<0.1	13	35	Chalk	4 of 4
CP03 (S)	15.1	56.6	14.2	27.4	0.3	6.9	<0.1	0.1	1	10	Landfill	0 of 4
CP03 (D)	<0.1	0.1	0.2	0.6	20	20.9	<0.1	<0.1	14	35	Chalk	4 of 4
CP05 (S)	22	52.1	16.6	26.3	<0.1	7.3	<0.1	<0.1	1	10	Landfill	0 of 4
WYG												
CP01 (S)	67.5	70.6	28.2	30.6	0	0.2	-0.5	0.3	1.0	11.0	Landfill	0 of 6
CP02 (S)	0.2	35.9	0.2	24.6	0.2	19.9	-0.2	6.1	1.0	9.0	Landfill	0 of 6

CP03 (S)	19.8	24.9	18.8	22.3	0	0.6	-5.9	31.11	1.0	10.0	Landfill	0 of 6
CP04	61.0	63.9	30.1	31.2	0	0.2	-0.5	-0.3	1.0	9.0	Landfill	0 of 6
CP05	40.8	49.6	26.2	28.0	0.0	0.4	-0.5	0.0	1.00	10.00	Landfill	0 of 6
CP06	55.0	60.1	2.3	23.2	0.0	2.1	-0.6	0.0	1.0	9.0	Landfill	0 of 6
WS01	0.7	64.9	0.8	31.8	0.0	20.5	-0.4	0.14	1.0	2.7	Landfill	0 of 6
WS02	62.8	64.5	18.1	28.7	0.0	0.3	-0.5	0.0	1.0	5.0	Landfill	0 of 6
WS03	27.6	40.8	20.1	26.2	0.1	4.0	-0.4	0.0	1.0	3.0	Landfill	0 of 6
WS04	43.0	66.6	223.3	31.8	0.0	5.9	-0.5	0.2	1.0	4.0	Landfill	0 of 6
WS05	0.1	33.0	2.9	23.6	0.0	18.1	-0.5	-0.1	1.0	3.0	Landfill	0 of 6
WS06	65.1	69.9	28.6	30.7	0.0	0.8	-0.5	-0.1	1.0	5.0	Landfill	0 of 6
WS07	60.7	98.2	28.0	29.7	0.1	0.4	-0.5	0.0	1.0	3.0	Landfill	0 of 6
WS08	51.0	60.0	20.7	25.1	0.0	0.36	-0.6	-0.1	1.0	3.5	Landfill	0 of 6
WS09	49.2	51.5	20.4	21.0	0.2	1.0	-0.4	1.0	1.0	4.0	Landfill	0 of 2
WS10	39.6	46.2	16.5	18.0	0.0	0.7	-0.6	-0.1	1.0	4.0	Landfill	0 of 6
CP01 (D)	56.7	67.6	26.5	30.1	0.2	2.5	-0.6	0.3	14.0	35.0	Chalk	6 of 6
CP02 (D)	0.0	22.5	0.2	15.3	7.7	20	-0.4	-0.1	13.00	35.00	Chalk	6 of 6
CP03 (D)	0.0	15.9	0.2	14.9	3.7	20.9	-6.3	0.0	14.00	35.00	Chalk	6 of 6

4.10.2 Continuous Monitoring

The boreholes installed within the landfill waste mass by Delta-Simons were designed in order to allow the mobilisation of continuous ground gas monitoring devices. Six boreholes in total were monitored for a period of four weeks each. The boreholes were spread across the Site to provide general coverage within the east and the west cells.

The table below shows the percentage of the monitoring period that methane and carbon dioxide concentrations were above specified concentrations.

Exploratory Hole	**% of monitoring period that gas concentration equalled or exceeded:**					
	Methane			**Carbon Dioxide**		
	1 % v/v	**5 % v/v**	**20 % v/v**	**5 % v/v**	**10 % v/v**	**30 % v/v**
RO101 (S)	100	100	100	100	100	0
RO102 (S)	100	100	100	100	100	0
RO103 (S)	100	99.5	99	99.3	98.9	0
RO104 (S)	100	100	100	100	100	0
RO105 (S)	100	80.9	11.3	100	100	0
RO106 (S)	99.8	97.7	78.9	-	-	-

The table below summarises the steady state minimum / maximum concentrations and flow rates recorded over the respective continuous monitoring periods.

Exploratory Hole	Steady Gas Concentration (%v/v)						Steady Flow Rate (l/hr)		Response Zone (m bgl)		Stratum
	Methane		Carbon Dioxide		Oxygen						
	Min	Max	Min	Max	Min	Max	Min	Max	From	To	
RO101 (S)	30.9	54.3	21.6	26.5	0.0	3.9	-0.05	0.94	1.5	10.5	Landfill
RO102 (S)	44.9	64.8	20.3	26.4	0.0	4.8	-0.67	2.55	3	8	Landfill
RO103 (S)	2.5	65.5	1.0	26.5	0.0	19.1	-0.24	1.78	3	9	Landfill
RO104 (S)	20.2	32.2	16.6	23.2	0.0	5.0	-0.04	18.6	1.5	10	Landfill
RO105 (S)	3.6	25.4	13.9	19.0	1.8	6.1	-0.25	0.16	2	10.5	Landfill
RO106 (S)	0.6	60.0	0.0	22.9	0.0	3.6	-0.05	0.32	2	13.5	Landfill

4.10.3 Atmospheric Pressures

Barometric pressures ranged from 1004 mB (4th May 2021) to 1031 mB (22nd March 2021) during the conventional spot gas monitoring visits undertaken by Delta-Simons and 1008 mb (17th June 2017) to 1024 mb (25th May 2017) during the visits undertaken by WYG.

During the Ground Gas Solutions monitoring atmospheric pressure ranged from 992 mB (16th May 2021) to 1031 mB (15th April 2021). The most significant atmospheric pressure drop event during this monitoring was a 21 mB fall over a 14-hour period on 3rd May 2021. During this falling pressure event, the maximum pressure change was 1.50 millibars per hour. Over the entire monitoring period falling pressure was recorded for approximately 16.6% of the time.

The charts below, taken from the GGS report, demonstrate the atmospheric pressure change over the eight week period of continuous monitoring. The chart also shows the 'worst-case' scenario that was captured on one occasion.

Diagram 4 – Atmospheric Pressure Change Over Eight-Week Monitoring Programme

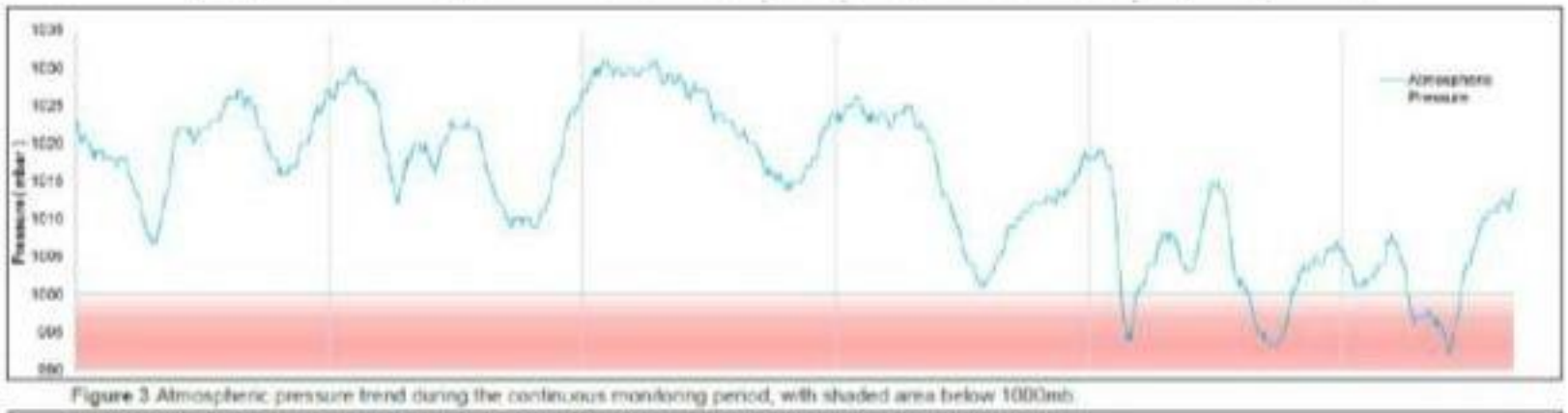


Figure 3 Atmospheric pressure trend during the continuous monitoring period, with shaded area below 1000mb



Figure 4 8-hour average atmospheric pressure trend during the continuous monitoring period

4.10.4 Purge and Recovery Test

Four monitoring well locations (RO101, RO103, RO104, RO106) were subject to a GGS Purge and Recovery Test (GGS PRT®) to provide an indication of ground-gas flux.

The GGS PRTs® were undertaken on 20th April 2021. The monitoring wells were purged using nitrogen until carbon dioxide, methane and oxygen fell to negligible levels, or to as low as possible; a GasClam® instrument was then immediately installed, sealed into the monitoring well with a rubber neck collar, and each instrument activated to measure the ground gas recovery at high frequency, in this case at three-minute intervals.

The GasClam® recorded data at this frequency for up to an hour, or until ground-gas concentrations reached a plateau. The results from GGS PRT® tests are summarised below.

Exploratory Location	CH_4 Flux (litres/hr)	CO_2 Flux (litres/hr)
RO101	6.696	3.895
RO103	9.347	4.730
RO104	N/A	N/A
RO106	5.590	3.416
N/A = Flux calculations were not made for RO104 as no significant recovered was observed in the hour preceding each test		

5.0 Geotechnical Assessment

5.1 Summary of Development Proposals

The proposed development at the Site comprises the construction of new employment units, providing up to 29,000m^2 (gross internal area) for flexible use across use Classes E (light industrial), B2 (general industrial) and B8 (distribution and storage) with ancillary offices, car parking, service yards, drainage works, landscaping and associated works to prepare the Site for development.

Hardstanding areas to facilitate car parking and yards are proposed to be situated around the buildings, with areas of soft landscaping/bunds towards the perimeter of the Site. Entrance to the Site will be via Harts Farm Way, with ease of access to the heavy goods vehicle (HGV) docking stations. A cut and fill earthworks operation will be required to facilitate the proposed units.

The following drawings have been made available to Delta-Simons for review:

- Drawing 1: Site Layout Plan;
- Drawing 3: Earthworks analysis presenting preliminary cut and fill balance and finished floor levels (FFL); and
- Drawing 4: Indicative landscape sections presenting bund locations, approximate levels and slope gradients.

5.2 Earthworks

It is understood that earthworks will be required as part of the proposed development, which will include the re-use of existing Made Ground soils in a significant Site wide cut and fill operation. These works need to be coordinated with the ground improvement specification and methodology adopted for the Site.

Based on levels provided in Drawing 3, current Site levels are highest in the eastern area of the Site, at approximately 14.0 m AOD. In the western area of the Site, levels typically range between 10.5 – 11.0 m AOD.

Testing undertaken predominantly on the re-engineered cover system, comprising predominantly of cohesive soils with granular lenses can be classified as either Class 1A/1B, 2A/2B or 2C, in general accordance with *Specification for Highways Works, Series 600, Table 6/2.*

5.2.1 Proposed Unit 1

Unit 1 is situated predominantly across the western landfill. The proposed indicative FFL for the warehouse is 11.3 m AOD. As such, the majority of the warehouse footprint will be raised by an approximate 0.5 m. Where Site levels fall away to the central and lowest area of the Site, levels are increased by c. 0.50 – 1.00 m. The north-east corner, where current elevations are the lowest, will be raised by c. 1.0 – 2.0 m.

5.2.2 Proposed Units 2

Units 2 is situated predominantly across the eastern landfill. The proposed indicative FFL for the warehouse 12.0 m AOD. Site levels will be reduced by the greatest amount in the north-western corner of Unit 3 by c. 2.5 – 3.5 m. The rest of Unit 2 has a maximum cut of circa 2.0 m. The south-eastern area of the unit is currently slightly below SSL and will require localised level increases.

5.2.3 Implications for Ground Improvement

Considering the proposed indicative level changes across Unit 1 and Unit 2, the cut and fill plan therefore suggests that the eastern area of the Site will undergo a net reduction in levels, whilst western areas of the Site will undergo a net increase in levels.

Area	Cut / Fill	Approximate Existing Elevation (m AOD)	Proposed Structure Surface Level (m AOD)	Max Landfill Waste Thickness (m)
West	Fill	10.5 – 11.0	11.3	9.0
East	Cut	14.0	12.0	12.4

Cut in the east of the Site will likely comprise the re-engineered cover system soils and / or landfill waste. The landfill waste is not considered to be geotechnically suitable for re-use at the Site notwithstanding that the EA's position is that the waste materials are not able to be reused on Site under a Materials Management Plan (MMP). Initial earthworks testing suggests that the cover layer may be suitable for use as a Class 2 acceptable earthworks material. In the western part the landfill waste is at its thickest and the level of cut is unlikely to significantly reduce this thickness.

In the west of the Site typically 0.5 m of fill is likely to be placed below the building footprint and a maximum of 2.0 m of fill is likely to be placed in the northeast corner. The loading of the ground is likely to induce immediate settlement and enhance ongoing consolidation settlement. Ground improvement should consider the thickness of landfill mass requiring treatment and the thickness of cover and newly placed fill.

5.2.4 Summary & Interpretation of Compaction Testing

The majority of samples scheduled for compaction testing were obtained from the eastern landfill cell, given that the area is proposed for a net cut, and reduction in levels to provide fill material for the western landfill cell.

The compaction test results indicates that the samples are at or are wet of optimum which suggests that the soil may require a reduction in moisture content (e.g., lime modification) in order to achieve a compaction criterion of at least 95 % maximum dry density and less than 5 % air voids.

5.3 Settlement Discussion

It is understood that the building structures will have a piled foundation solution and therefore it is only settlement in the external areas being considered as part of this appraisal. No settlement test data is available at the time of writing this report.

As stated in BRE document Building on fill: geotechnical aspects (Section 4.5), movements (without an imposed load) in refuse can be attributed to the following processes, of which biodegradation is considered to be the most important cause of settlement.

- Immediate settlement, caused during the placement of successive layers of fill;
- Creep – as particles become more closely packed over time (α_c); and
- Biodegradation – of the organic content of the refuse (α_b)

A preliminary assessment of settlement has been undertaken by WYG and is documented in WYG Report, Brockhampton West, A102760, dated August 2017. Settlement was calculated to be 0.018 m per year, 20 years following completion of the landfilling, and based on a maximum landfill thickness of 7.5 m.

The assessment has been revisited as part of this proposal to take into consideration the actual age of the landfill and time elapsed since landfilling ceased, and the thickness of landfill proven during Delta-Simons intrusive site investigation.

5.3.1 Landfill Information

As review of council documents undertaken as part Delta-Simon's scope indicates that the landfill was operational between 1969 and 1990, and therefore it has been 31 years since the landfilling ceased at the Site, with fill being placed over a duration of 21 years.

BRE states the following:

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 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.

We know that fill was placed in the landfill over a period of 21 years (between 1969 and 1987) and therefore it could be assumed that the landfilling was 75 % complete in 1985, 36 years ago. Future settlement without any ground improvement could therefore be estimated to be:

West

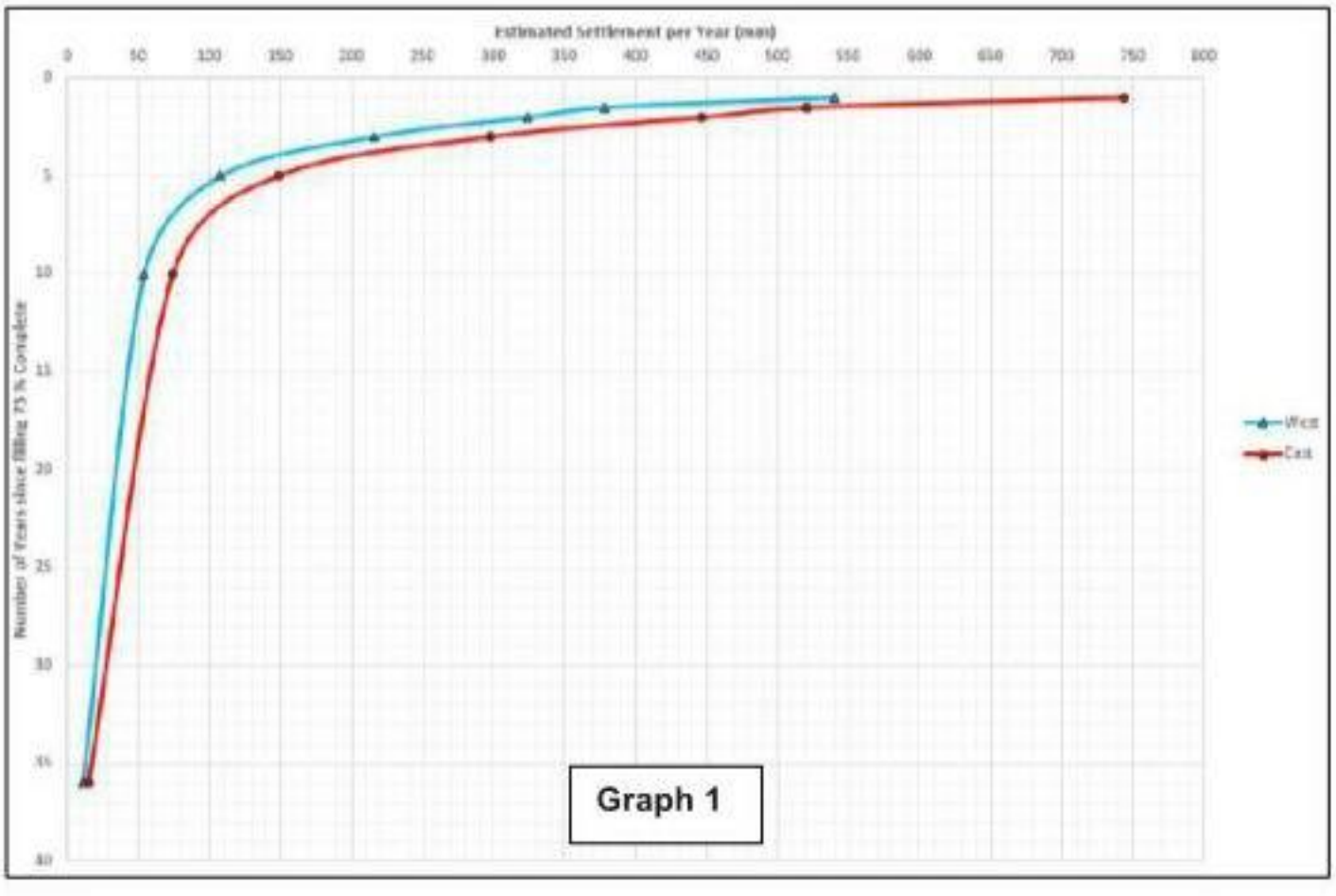
Rate of Settlement (Year 36) = 0.01 % x 9.0 m = 0.0009 m per month / 0.0108 m per year / 10.8 mm per year.

East

Rate of Settlement (Year 36) = 0.01 % x 12.4 m = 0.00124 m per month / 0.01488 m per year / 14.88 mm per year.

By using this theory, without a ground improvement solution, it is estimated that the landfill could continue to settle at rates of between 10 - 20 mm per year due to creep and biodegradation alone (likely to vary significantly across the different thickness, landfill material composition and across landfill boundaries). This is without the addition of loads associated with raising elevations at the Site, the placement of hardstanding, and parked plant / vehicles. The engineer approved solution will need to take into consideration revised levels, the placement of hardstanding, drainage and vehicle movements associated with units of this type.

Graph 1 below is based on the calculations above and is a plot of estimated settlement per year versus years since filling 75 % complete. It is useful for demonstrating how the rate of settlement reduces overtime.



Graph 1

5.3.2 Discussion

It is clear from the research that determining the rate of settlement of a landfill is not simple. As stated in the ICE manual of geotechnical engineering, Section 34.4.2.5. Settlement, secondary settlement of between 15 % and 50 % of the fill thickness has been suggested (Powrie et al., 1998) while Ling et al. (1998) gave figures of 30 – 40% for overall settlement.

By calculating cumulative settlement using the graph it is estimated that the East may possibly have already settled in the region of 4.1 m and the West in the region of 2.9 m, which is approximately 30 % of the fill thickness in both instances based on the percentages stated above by Powrie et al., and Ling et al.

In addition to this as part of our site investigation forensic waste testing was undertaken on shallow waste samples obtained from trial pits at depths ranging between 1.7 m and 3.5 m. The percentage of putrescible material recorded ranged between 2.1 % and 19.6 % which suggests that the majority of the waste is non-putrescible and therefore favourable in terms of settlement associated with biodegradation (however significant variation in composition could still be expected).

The information suggests that some settlement is likely to continue in external areas of the Site regardless of whether the ground is loaded or not. Loading the ground however is likely to accelerate the rate of settlement and without settlement trials (e.g., maintained load skip tests) it is difficult to predict what magnitude of movement this could be.

The CPT data recorded across the two landfill cells does not demonstrate an increase in derived SPT N value with depth. Equally, E' values derived from inferred 'Coefficient of Volume Change' (m_2/MN)' do not increase with depth, and generally range between E'= 4 – 10. Occasionally, very compressible material is recorded, yielding E' values of between 1 – 4, and less than 1 in certain localities. It is therefore reasonable to conclude that the landfill material does not consolidate with increasing depth, and as shown in CPT108, actually becomes less consolidated with increasing depth. The interpretation of the above data is included as Appendix C.

In order to limit settlement a ground improvement solution is recommended across external areas of the Site to prevent damage to drainage runs etc. and mitigate the potential for differential settlements between external areas, piled buildings, and landfill boundaries.

It is recommended that a ground improvement specialist is consulted to design a suitable solution at the Site, taking into consideration the proposed elevations and landfill thicknesses requiring treatment, environmental constraints and programme.

5.4 Foundations (Buildings)

Given that the underlying ground model at the Site comprises two landfill cells, typically comprising heterogeneous and unpredictable materials such as landfill waste, shallow spread foundations are not suitable for the proposed structures.

5.4.1 Piling

A piled foundation solution using pre-cast concrete driven piles transferring loads to competent Chalk geology may be suitable for the expected design loads, utilising both skin friction and end bearing capacity.

The precise method of pile installation and applicability of proprietary systems, diameters and depths required would need to be informed based on the results of this investigation, by discussions with a piling contractor with suitable experience in Chalk.

Individual pile/pile group loads will be a function of the surface area of the piles to be employed at the Site and their method of construction.

Due to the heterogeneity of landfill waste, and data gathered during CPT operations, there is the possibility that piles may refuse within the landfill cell due to obstructions. Such risks should be considered prior to the commencement of piling and mitigating measures such as pile probing maybe prudent to undertake in required locations if deemed necessary.

Normal static and dynamic load testing (including uplift tests) should be considered to achieve satisfactory quality control/assurance in accordance with good practice.

There will be a requirement for the placement of a suitably engineered piling mat, which should be designed and validated by a suitably qualified and experienced engineer.

5.5 Floor Slabs

The ground model in its existing form and profile, comprising Made Ground topsoil (where applicable), re-engineered cover system and landfill waste is not suitable for a ground bearing floor slab.

Where areas of fill are proposed as part of the wider earthworks scheme, a ground bearing floor slab maybe suitable subject to the placement of material to an engineered specification.

In areas of cut, notably in the eastern areas of the Site, it is likely that exposed soils will require a form of ground improvement in order to improve the formation level, prior to the placement of a ground bearing floor slab.

5.6 Ground Improvement Techniques (External Areas)

Ground improvement techniques should be considered for external areas which could consist of the following options which are not exhaustive:

- Controlled Modulus Columns (CMC);
- Bi-Modulus Columns;
- Dynamic Compaction/ Rapid Impact Compaction; and
- High Energy Impact Compaction (HEIC).

The design and build contractor will propose the ground improvement technique or indeed techniques for the approval of the civil / structural engineer.

5.7 Proposed Bunds and Slopes

In reference to Drawing 3, the table below summarises the approximate geometry of the proposed bunds and slope. Note that section C – CC is considered a slope for the purpose of this assessment:

Bund Section	Approximate Vertical Height of Bund (m)		Proposed Gradient
A – AA	4.75		1 in 2 (50 % Grade) (26.5°)
B – BB	5.00		
	Slope[1] Height (m)	Slope[2] Length (m)	
C – CC	10	50	1 in 5[3] (20 % Grade) (11.3°)

Notes:
1. Slope height is derived from the elevation change between the end of the section line (CC), and the elevation at the foot of the proposed retaining wall adjacent to Unit 2, as shown on the section plan.
2. Slope length is approximate and measured from the proposed retaining wall to the end of the section line.
3. Approximate gradient calculated based upon a slope length of 50 m and a height of 10 m.

Delta-Simons has assumed that the excess re-engineered cover system generated from the Site wide cut and fill, comprising predominantly of cohesive clay soils will be utilised to form the proposed bunds (A – AA and B – BB) as summarised above.

At proposed bunds A – AA and B – BB the formation is likely to comprise re-engineered cover system clays or landfill waste, dependent on the maximum extent of the proposed cut and fill. In either scenario, the formation is likely to comprise of highly compressible strata.

As mentioned in section 4.7.3, the cohesive re-engineered cover system material tested classifies as a Class 2A/2B and 2C in reference to *Specification for Highways, Series 600, Table 6/2*. One sample classified as Class 1A/1B due to the more granular composition in the affected sample, however, the particular stratum in question is predominantly cohesive. As such, it is considered that the cohesive re-engineered cover system material is likely to be suitable for re-use in this regard.

Although Delta-Simons intrusive site investigation did not specifically target the proposed bund locations, the following borehole locations are considered appropriate at this stage to inform preliminary advice:

- Section A – AA = RO107;
- Section B – BB = RO108; and
- Section C – CC = RO105/DS103.

Assuming a maximum plasticity index value of 25, and a drained shear strength of 0 kPa for cohesive re-engineered cover system material, an indicative residual drained angle of shearing resistance of 27° is likely to be appropriate.

Given that bunds A – AA and B – BB are currently proposed to comprise gradients of 1 in 2 (approximate slope angle of 26.5 °), it is likely that the proposed slope may be considered to be unstable (when taking into account relevant safety factors) and a detailed slope stability analysis is recommended.

From calculations derived by Delta-Simons, slope C – CC comprises a proposed gradient of 1 in 5 (approximate slope angle of 11°). Given the shallower gradient, instability is unlikely to be an issue.

5.8 Retaining Structures

In reference to Drawing 3, five retaining structures varying in length have been proposed for the Site as part of the wider earthworks program. It is understood that the proposed retaining structures are to comprise pre-cast concrete blocks:

Proposed Retaining Wall (RW)[1,4]	Dimensions of Retaining Structure (L x H^2)	Proposed Approximate Elevation[3] (m AOD)	Anticipated Founding Strata
Retaining Wall 1	270 m x 4.4 m	7.60	Made Ground Landfill
Retaining Wall 2	72 m x 3.7 m	8.30	Made Ground Re-engineered cover system/Landfill
Retaining Wall 3	135 m x 3.2 m	8.80	
Retaining Wall 4	65 m x 1.6 m	9.70	Made Ground Re-engineered cover system
Retaining Wall 5	40 m x 1.0 m	10.30	Earthworks fill material comprising Made Ground Re-engineered cover system

Notes:
1. Assuming a indicative finished floor level of 12.00 m AOD for RW 1 – 3, and FFL of 11.30 for RW 4 & 5.
2. Heights of proposed structures are maximal. It is assumed the height of structures will vary depending on final Site elevations following cut and fill.
3. Elevations at the base of retaining walls are expected to change corresponding with retaining wall height. Minimum elevations have been calculated based off maximum structure heights.
4. Due to access restrictions, borehole locations are generally not positioned in close proximity to retaining structures in certain locations, most notably the access road accompanied by RW 3. A best likely estimate has therefore been provided for founding strata and anticipated elevation.

Based on the information summarised above from Drawing 3, it is considered likely that RW 1 and 2 will encounter landfill waste at founding level, situated in the east of the Site (eastern landfill cell) following the cut

operation. In the west of the Site, RW 4 will likely found upon re-engineered cover system material, and RW 5 will likely found on engineered fill placed as part of the fill operation in the western Site area (western landfill cell).

At this stage, it is likely that structures bounding the eastern landfill cell will require piling. Subject to settlement tolerances and loadings for RW structures 4 and 5, shallow spread foundations maybe feasible. Should expected loadings and settlement tolerances exceed what is required, ground improvement or piling may be suitable alternative solutions.

Although beyond the remit and expertise of Delta-Simons, it is considered necessary to consider the impact of lateral loadings and stresses, in addition to the proposed vertical loading of the various retaining structures. It would be prudent for the designer to consider the impact of lateral stresses in preliminary design.

The data provided from this investigation should be used to inform the design of retaining features proposed for the Site.

5.9 Groundwater

Section 4.4.4 above summarises the general hydrogeological regime identified at the Site, comprising two groundwater bodies; one body is situated in the landfill, and the other situated in the underlying Lewes Nodular Chalk Formation.

Several groundwater seepages were observed in trial pits undertaken within the landfill mass. In areas of cut, it is likely that the risk of encountering shallow groundwater ingress in shallow excavations will increase in this regard.

With regards to future pile design, the contractor will need to take the fluctuating hydrogeological regime into account, due to the tidal influence on groundwater, and the corresponding ingress and egress of groundwater over tidal cycles.

5.10 Roads and Pavements

Based on the understanding that cut and fill operations are proposed for the Site, and ground improvement is to be utilised to improve and stabilise the achieved formation level for areas of hardstanding, indicative CBR values are likely to change as earthworks progresses.

A preliminary CBR value of 1% can be assumed for the ground model in its current form, however is likely to be highly variable due to the compressibility of the ground model.

It is therefore recommended that incremental plate CBR tests are undertaken on ground improved soils once formation level is achieved in order to inform preliminary pavement and highways design.

5.11 Excavations & Obstructions

It is expected that conventional mechanical excavators will readily remove Made Ground soils such as the re-engineered cover layer, and landfill waste likely to be encountered in shallow excavations.

All shallow foundation or services excavations at the Site should be considered unstable, therefore, temporary support of all excavations should be considered when excavating on-Site.

5.12 Chemical Attack on Buried Concrete

Based on the ground model identified at the Site, it is likely that the main source for the generation of aggressive ground conditions is the Made Ground landfill waste and associated leachate. The main receptor for the potential impact of aggressive ground is likely to be the pre-cast driven piles, CMC grouted piles in the yard area (if utilised) advanced through the two landfill cells.

In accordance with the recommendations of BRE Special Digest 1, 'Concrete in Aggressive Ground' 2005, the conditions of the soils at the site would be classified as Design Sulphate Class DS-3 and ACEC Class AC-3 for soils and groundwater, when considering the most appropriate type of concrete to be used at the site in order

to resist chemical attack from elevated sulphate present in the soils (assuming mobile groundwater in potentially pyritic soils).

With regard to ammonium within the groundwater, it is stated within BRE Special Digest 1, 'Concrete in Aggressive Ground' 2005 that UK guidance is not available on the concentration of ammonium ions that can be tolerated by different types of concrete. However, BS EN 206-1, Table 2, does indicate that a level of NH4 of 15–30 mg/l should be regarded as slightly aggressive, 30–60 mg/l as moderately aggressive, and greater than 60 mg/l as highly aggressive.

Ammonium values within the groundwater ranged from 0.015 to 250 mg/l. Of the 25 groundwater samples taken from the wells installed within the waste, ammonium levels were elevated above 60 mg/l in 16 samples (maximum concentration 250 mg/l). All groundwater samples taken from the RTD recorded ammonium concentrations above 60 mg/l (maximum concentration 190 mg/l) as well six out of 38 samples taken from the Chalk wells (maximum concentration 140 mg/l).

The data suggests that the concentrations of ammonium within the groundwater (predominantly the perched groundwater within the landfill waste and RTD) present 'highly aggressive' conditions with regard to buried concrete and the guidance suggests that specialist advice should be sought in this instance.

5.13 Geotechnical Risk Register

A Geotechnical Risk Register has been compiled to show the degree of risk attached to various ground related aspects of the proposed development. The purpose of the register is to provide an assessment of the risk to the project posed by common ground related problems and identify suitable mitigation measures that control the risk to an acceptable level. The risk register should be developed and refined as the geotechnical design and assessment progresses such that the register will allow the management of the geotechnical risks.

The preliminary risk register for the scheme is presented in Appendix D and identifies geotechnical hazards/risks associated with the construction phase.

6.0 Generic Quantitative Risk Assessment

6.1 Introduction

The presence of hazardous substances in or on a Site is generally only of concern if an actual or potential unacceptable risk exists. Legislation and guidance on the assessment of contaminated sites, consistent with UK best practice, acknowledges the need for a tiered risk-based approach. A Preliminary Risk Assessment is presented in Section 2.2. This section represents a Generic Quantitative Risk Assessment (GQRA) being a comparison of site contaminant levels against Generic Assessment Criteria.

6.2 Human Health GQRA

The assessment of risks in relation to human health has been undertaken using Generic Assessment Criteria (GAC) as detailed within the appropriate tables. Risks from soil, groundwater and Non-Aqueous Phase Liquids (NAPL) have been considered. The GAC are predominantly based on long term (chronic) risk to health. However, in the limited circumstances where short-term (acute) risks are more pronounced, these GAC have been utilised to ensure a thorough and conservative initial assessment is undertaken.

The end use scenario adopted for the assessment is a commercial end use, considered appropriate based on the proposed commercial development.

6.2.1 Risks from Soil Sources

Based on the proposed use of the Site for commercial use, the soil and groundwater chemical data has been compared against a commercial end use GAC for 1% soil organic matter (SOM) content.

Asbestos

The asbestos findings for both Delta-Simons and WYG investigations are summarised in the table below.

Exploratory Location	Depth (m bgl)	Strata	Asbestos Type	Location	Description
Delta-Simons					
TP116	2.0 – 2.5	Landfill Waste	Amosite	Central-North (West Cell)	Amosite loose fibres
WYG					
CP02A	4.5	Landfill Waste	Chrysotile and Amosite	South-West (West Cell)	Fibre bundles
	7.0	Landfill Waste	Chrysotile		Fibre bundles
CP04	0.5	Re-Engineered Cover System	Chrysotile	Central North-West (West Cell)	Fibre bundles
	4.5	Landfill Waste	Chrysotile		Fibre bundles
CP05	4.2	Landfill Waste	Chrysotile	South (West Cell)	Fibre bundles
	9.5	Landfill Waste	Chrysotile		Fibre bundles
CP06	2.5	Landfill Waste	Chrysotile	South-East (East Cell)	Asbestos cement debris

TP01	3.4	Landfill Waste	Chrysotile	North-West (West Cell)	Fibre bundles
TP03	0.4	Re-Engineered Cover System	Chrysotile and Amosite	Centre (West Cell)	Insulting board debris
TP06	2.0	Landfill Waste	Chrysotile	East (East Cell)	Fibre bundles
	3.1	Landfill Waste	Chrysotile		Insulation debris
TP08	2.3	Landfill Waste	Chrysotile	South-East (East Cell)	Asbestos cement debris
	3.2	Landfill Waste	Chrysotile		Fibre bundles
TP10	3.3	Landfill Waste	Chrysotile	Centre (West Cell)	Fibre bundles
TP11	2.5	Landfill Waste	Chrysotile	West (West Cell)	Fibre bundles

16 positive asbestos results (out of 84 samples tested) were identified across Site, which were predominantly located within the landfill waste. However, asbestos fibre bundles and insulating board debris were also recorded by WYG within the shallow (less than 0.5 m bgl) re-engineered cover system materials in two locations.

The primary pathway for asbestos is considered to be inhalation of fibres. Considering this and given the nature of the Site, it would be prudent to assume that asbestos containing materials (ACMs) are likely to be present within the landfill waste and re-engineered cover system across the Site, and the risk to human health should be mitigated as appropriate. Mitigation measures should be detailed within a Site-specific Remediation Strategy; however, this would typically comprise a clean cover system in any soft landscaped areas where existing re-engineered cover system material or landfill material remains at the surface (e.g. proposed bunds).

As there were no asbestos detects within the existing topsoil, it is considered this material should be suitable for retention and reuse within areas of soft landscaping, as part of the clean cover system. This would be subject to careful separation or segregation from the re-engineered cover system and appropriate stockpile management. Additionally, it is recommended that further sampling and analysis is undertaken on this material prior to its re-use within any proposed landscaping / clean cover system.

The presence of asbestos within the re-engineered cover system soils does not prevent the re-use of the soils within the cut/fill earthworks programme. However, management of the health & safety risks to any groundworkers would need to be appropriately managed. Further to this should any bulk asbestos/ACMs be encountered during the groundworks; works should cease until appropriate management under the Control of Asbestos (CAR 2012) has been determined.

Volatile Organic Compounds (VOCs)

Concentrations of 1,1-dichloroethane, 1,1,1-trichloroethane, trichloroethene, toluene, tetrachloroethene, ethylbenzene, p & m-xylene and o-xylene were recorded within the landfill waste above the LOD (0.001 mg/kg) but below the respective GAC. The concentrations were generally between two and five magnitudes less than the GAC. As the concentrations are significantly lower than the GAC, they are not considered to pose a significant risk of contamination.

Concentrations of dibromomethane, isopropylbenzene, n-propylbenzene, 1,3,5-trimethylbenzene, sec-butylbenzene, p-isopropyltoluene and butylbenzene were recorded above the LOD (0.001 mg/kg) but have no relevant GAC. The concentrations were between one and three magnitudes greater than the LOD. The maximum concentration recorded was for dibromomethane recorded at 1.3 mg/kg. Generally, the concentrations elevated above the LOD appeared to be widespread within the landfill waste, between 1.0 m and 11.5 m bgl. Whilst the concentrations are elevated above the LOD, up to three magnitudes in some cases,

the concentrations are still considered to be minor and so are not considered to pose a significant source of contamination specifically via the inhalation of vapours pathways.

Polycyclic Aromatic Hydrocarbons

One concentration of dibenzo(a,h)anthracene was elevated above the respective GAC (4.72 mg/kg compared to 3.5 mg/kg) recorded as part of the WYG investigation. The exceedance was located in the central-south of the Site (TP09), within the shallow re-engineered cover system at 0.4 m bgl.

The strata in which the elevation was encountered, dark brown / black sand and gravel, was relatively thin (0.2 m) and was not recorded within the closest exploratory locations to TP09. As such, the concentration is considered to represent localised contamination, given no other exceedances have been encountered by Delta-Simons or WYG.

Additionally, dibenzo(a,h)anthracene is considered to be non-volatile, as such, the main risk associated with human health for consideration is the ingestion pathway. Given the proposed commercial development, the minorly exceeding concentration and the limited nature of contamination it is considered this elevation does not pose a significant risk to human health receptors.

Other Contaminants

No other of the contaminant concentrations reported in soil exceeded the relevant Generic Assessment Criteria (GAC). Therefore, the soil contaminant concentrations are not considered likely to represent a risk to human health.

The soil analysis results are considered further in the Conceptual Site Model (CSM) presented in Section 8.0 with regard to potential contaminant linkages.

6.2.2 Risks from Groundwater Sources

Based on the proposed use of the Site for commercial use, the soil and groundwater chemical data has been compared against a commercial end use GAC to assess risks from groundwater sources to indoor air and subsequent vapour inhalation indoors.

None of the site-specific contaminants of concern were recorded at concentrations in excess of their detection limits/respective GAC within the Delta-Simons and WYG investigations.

The water analysis results are considered further in the Conceptual Site Model (CSM) presented in Section 8.0 with regard to potential contaminant linkages.

6.2.3 Risks from Non-Aqueous Phase Liquids (NAPL)

Soil and groundwater exposure models used in generating Generic Assessment Criteria do not account for the potential for NAPL to represent a source of risk to human health, principally due to the production of vapours. Whilst it is possible to calculate theoretical soil saturation limits, in reality, due to co-solubility effects, these are not an appropriate indicator of the presence of NAPL. In order to assess the presence of NAPL, for petroleum hydrocarbons, an assessment criterion of 5,000 mg/kg has been applied based on professional experience.

The following has been identified in relation to NAPL at the Site:

- A sample of the landfill waste at 2.3 m bgl from RO102 recorded concentrations of Total Petroleum Hydrocarbons (TPH) in excess of 5000 mg/kg (7632 mg/kg). A moderate hydrocarbon odour was noted throughout;
- Two samples (TP01 and TP04), analysed as part of the WYG investigation, detected TPH concentrations exceeding the GAC within the landfill waste (11,589 and 9,850 mg/kg respectively). Both strata descriptions noted a 'rotten type odour';
- Delta-Simons encountered slight to strong hydrocarbon odour / sheen in 13 samples during the intrusive investigation as well as recording other odours such as solvent, creosote and waste;
- WYG recorded rotten, ashy / burnt and foul odours within the landfill waste across the Site; and

- No NAPL was measured during groundwater monitoring works.

On this basis, there is limited evidence of localised potential NAPL sources which may represent a risk to human health in the context of vapour inhalation. Critically, there was no NAPL recorded in the groundwater which would suggest that potentially mobile NAPL has not been detected.

6.3 Controlled Waters/Water Environment GQRA

6.3.1 Groundwater Results

The approach adopted to assessing risks to Controlled Waters/Water Environment is based principally on considering the concentrations of contaminants identified within the groundwater samples obtained in comparison to relevant GAC.

Given the 'prevent and limit' approach of the Water Framework Directive (2000/60/EC) and the identified receptors, a range of Water Quality Standards (WQS) have been applied as Generic Assessment Criteria (GAC), these include Water Framework Directive standards and thresholds (WFD), the Freshwater Environmental Quality Standards (EQS), the UK Drinking Water Quality Standards (DWQS), WHO Guidelines for Drinking Water Quality or SEPA resource protection values which have been used as initial conservative GAC to assess whether groundwater contamination requires further assessment or discussion in terms of the risks to controlled waters. Where specific water quality standards are not available, Delta-Simons has adopted surrogate values based on professional judgement (DS GAC).

Groundwater contaminant concentrations that exceed the applied GAC are then considered in the context of the Site's environmental setting as to whether further qualitative or quantitative assessment is required as described in subsequent sections. Laboratory results above the GAC are summarised in the table included within Appendix E with a comparison to the GAC applied.

The groundwater chemical data has been compared against a GAC specifically for surface water receptors. Based on pre-Site investigation discussions with the Environment Agency the Hermitage Stream and Langstone Harbour are considered to pose the most significant risk in relation to contamination from potential landfill leachate.

The summary includes data from the WYG investigation and will also split the results into waste, superficial, Chalk and surface water for the purpose of assessing downward and lateral migration of contamination.

6.3.2 Surface Water Results

Delta-Simons undertook two rounds of surface water sampling from the Hermitage Stream, situated adjacent to the eastern boundary of the Site. One round of surface water sampling comprised the collection of an up, mid and downstream sample at high tide and low tide. Round 1 was undertaken following a period of relatively weather and Round 2 was undertaken following a recent storm / heavy rainfall event.

The surface water chemical data has been compared against a GAC specifically for surface water receptors (WFD 2015c). This will aid in the risk assessment for the Hermitage Stream which flows into Langstone Harbour. The results above the GAC are summarised below.

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedance	Tidal Conditions	Concentration (µg/l)	
								Round 1 (Dry)	Round 2 (Wet)
Copper	12	11	2.12	WFD 2015c	6	Upstream	High	5.8	6.8
						Midstream		11	2.5
						Downstream		8.3	9.4
						Upstream	Low	5	6.4
						Midstream		2.5	5.1
						Downstream		9.3	5

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedance	Tidal Conditions	Concentration (µg/l)	
								Round 1 (Dry)	Round 2 (Wet)
Zinc	12	31	23.1	WFD 2015c	1	Midstream	Low	31	<GAC
Chloride	12	11,000,000	188,000	WFD 2015c	6	Upstream	High	680,000	740,000
						Midstream		1,000,000	11,000,000
						Downstream		970,000	<GAC
						Downstream	Low	<GAC	290,000

Notes: <GAC = Concentration less than GAC
WFD 2015c - Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. Schedule 5 Table 1 - Threshold Values for Groundwater

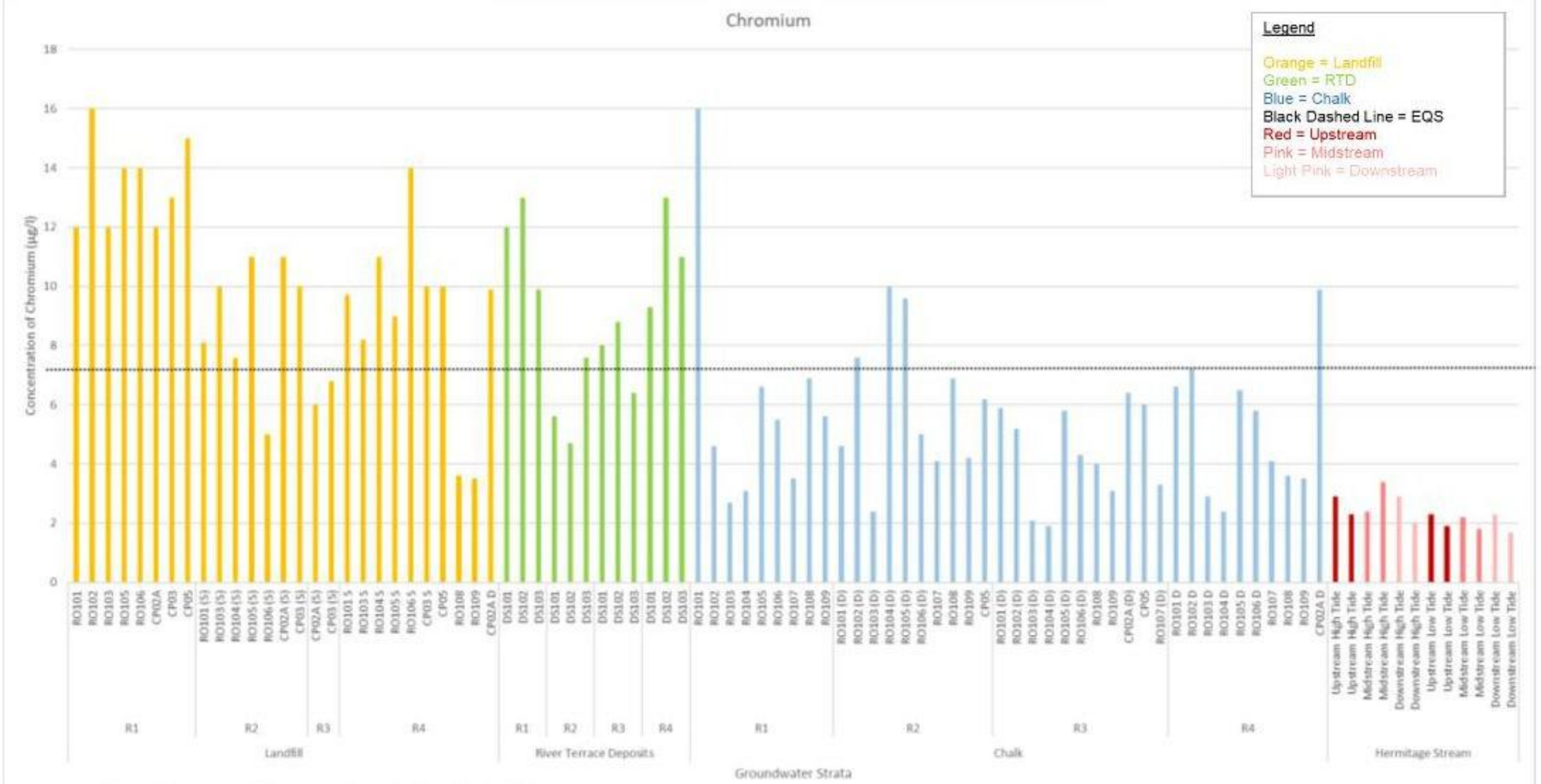
6.3.3 Groundwater and Surface Water Discussion

Chromium

Chromium concentrations were elevated above the GAC within the groundwater samples taken from the landfill waste, RTD and Chalk targeted boreholes. The concentrations were relatively similar across the three lithologies, however, the number of exceeding samples was significantly less within the Chalk, in comparison to the landfill waste and the RTD suggesting natural attenuation is occurring prior to any discharge into the stream. The difference in number of exceeding samples within each lithology as well as concentration is displayed in the graph below.

Natural attenuation processes for heavy metals are likely to be related to the low permeability of the upper Chalk and precipitation of metals based on pH and solubility range into the RTD/upper putty Chalk. Furthermore, whilst the elevated chromium concentrations appear to be widespread across the Site, they were not found to be exceeding the GAC in any of the Hermitage Stream samples further supporting that natural attenuation is occurring.

Diagram 5 – Chromium Concentrations in Groundwater and Hermitage Stream



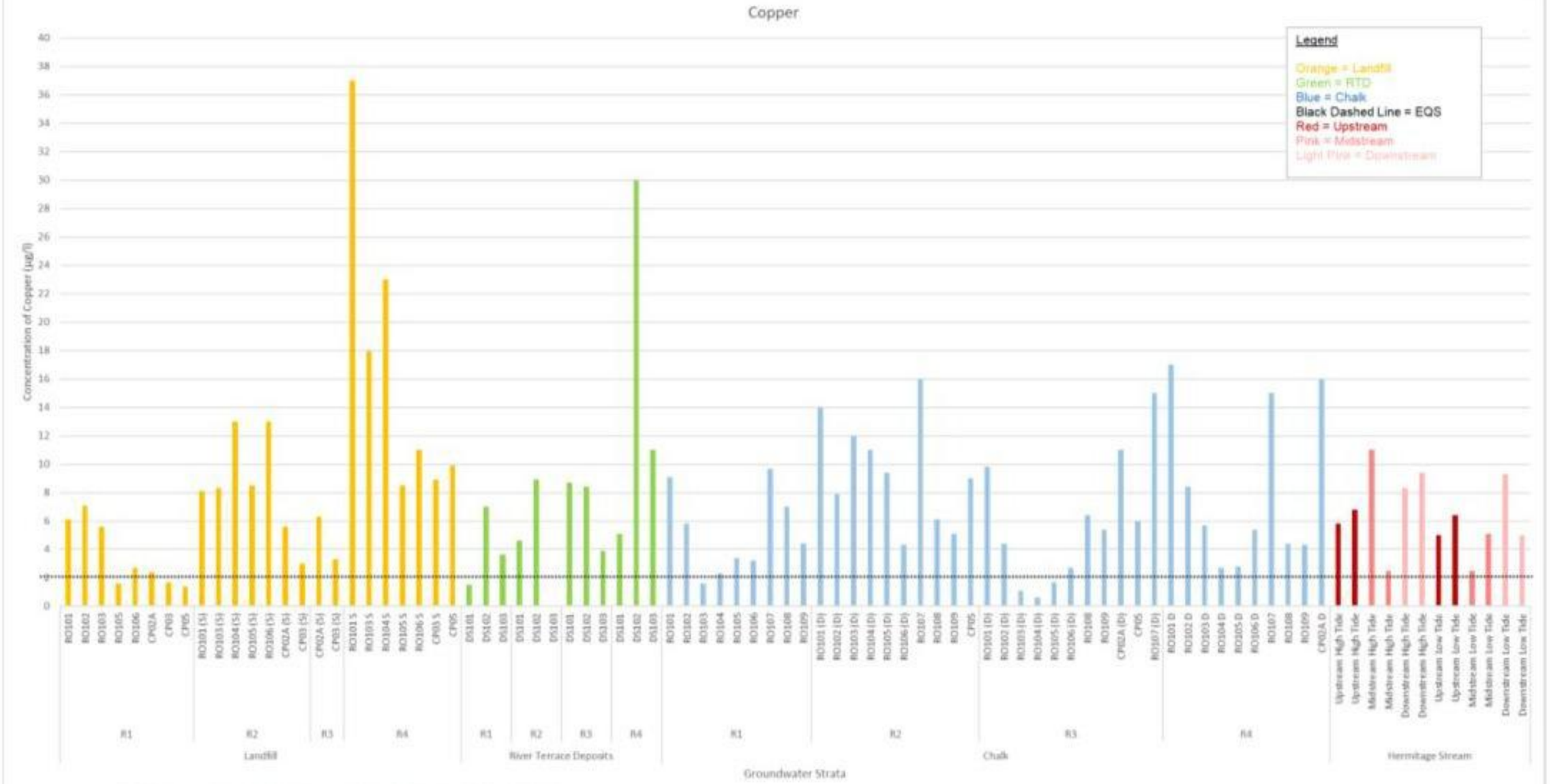
Copper

Copper was detected at concentrations exceeding the GAC in groundwater samples from all three lithologies. This indicates copper contamination within the waste leachate is migrating downwards, to some extent, into the Chalk aquifer. However, the number of samples detecting elevated concentrations of copper decreases with each successive lithology, indicating the contamination is generally less widespread within the Chalk, compared to the landfill waste and again is being naturally attenuated to some extent.

The graph overleaf, summarises the exceeding copper concentrations through each lithology the Hermitage Stream for comparison. The graph displays the maximum concentrations recorded within each stratum and how they significantly decrease as groundwater migrates downwards into the Chalk aquifer and laterally to the Hermitage Stream.

Whilst all samples collected from the Hermitage Stream detected concentrations above the GAC, three of the four upstream samples also recorded higher concentrations that those recorded at the midstream sampling point. Therefore, it is considered that the concentrations recorded within the Hermitage Stream are not entirely Site derived and there is an off-Site source of copper (potentially partially natural) contributing to the environmental quality of the Hermitage Stream.

Diagram 6 – Copper Concentrations in Groundwater and Hermitage Stream



Lead

Lead was detected within Chalk monitoring well RO104, at a concentration exceeding the GAC (19 µg/l) by an order of one magnitude. The exceedance was not reflected with the landfill waste groundwater data for the Site and as such, is anomalous and likely associated with an off-Site source. Additionally, the exceedance was only encountered on one out of four sampling rounds and so, it is not considered to represent a consistent or significant source of contamination.

Mercury

Concentrations of mercury were encountered within DS103 (installed within the RTD) at a concentration marginally above the GAC on one of the four groundwater sampling rounds. Based on this, it is not considered likely that mercury is having an ongoing detrimental effect upon the quality of the groundwater within this area of the Site. Additionally, mercury was not detected above the GAC for any of the landfill waste samples across the Site and so, the exceedance is potentially associated with an off-Site source via the stream and flushing of the RTD/Chalk on a twice daily basis tidal cycle.

Mercury was also detected at concentrations above the GAC (all <1 µg/l) within RO107 (installed within the Chalk) within every sample collected over the four rounds of monitoring. The surrounding boreholes did not record concentrations of mercury above the GAC and these concentrations were not replicated in the landfill waste data. It is likely these elevations represent a highly localised mercury hotspot within the groundwater and, the data indicates, the hotspot is not having a detrimental effect on the quality of the groundwater across the Site. As such, the risk posed by mercury is considered to be low.

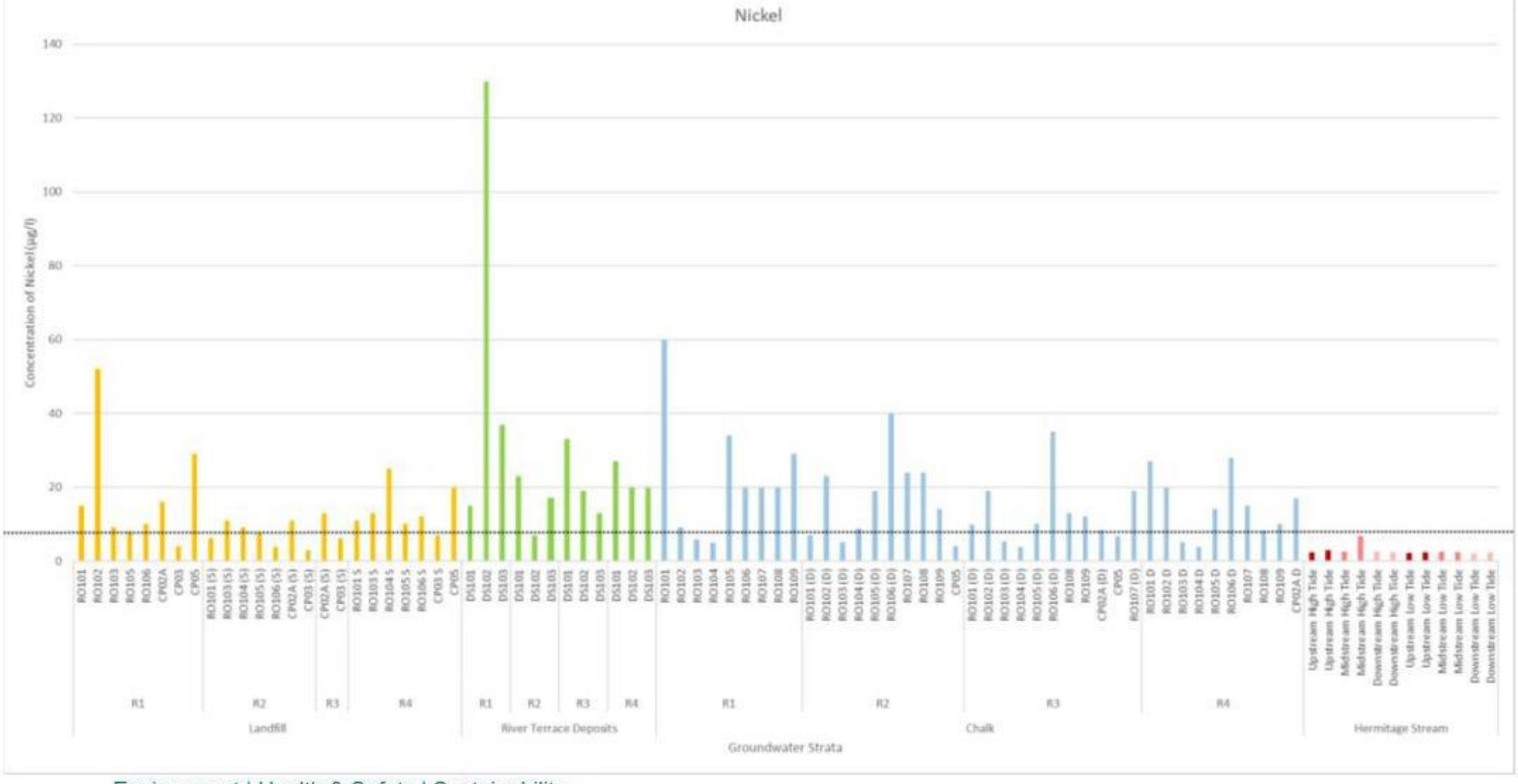
Nickel

Exceeding concentrations of nickel above the GAC were detected within the groundwater, across the Site, within all lithologies across the four rounds of monitoring. The concentrations of nickel were generally marginally higher and more prevalent within the Chalk. This is demonstrated in the graph below.

Whilst the landfill waste clearly represents a source of nickel contamination, through downward migration of leachate; the concentrations within the Chalk are up to one magnitude greater. As such, it is likely that there is some contribution from an off-Site source and/or accumulation within the Chalk, accounting for the elevated concentrations within the Chalk.

Nickel was not detected at concentrations above the GAC within the Hermitage Stream and so, whilst migration and potential accumulation of nickel is occurring into the Chalk aquifer lateral migration into the stream is being attenuated by the most likely dilution. Therefore, the risk associated with nickel contamination is considered to be low.

Diagram 7 – Nickel Concentrations in Groundwater and Hermitage Stream



Zinc

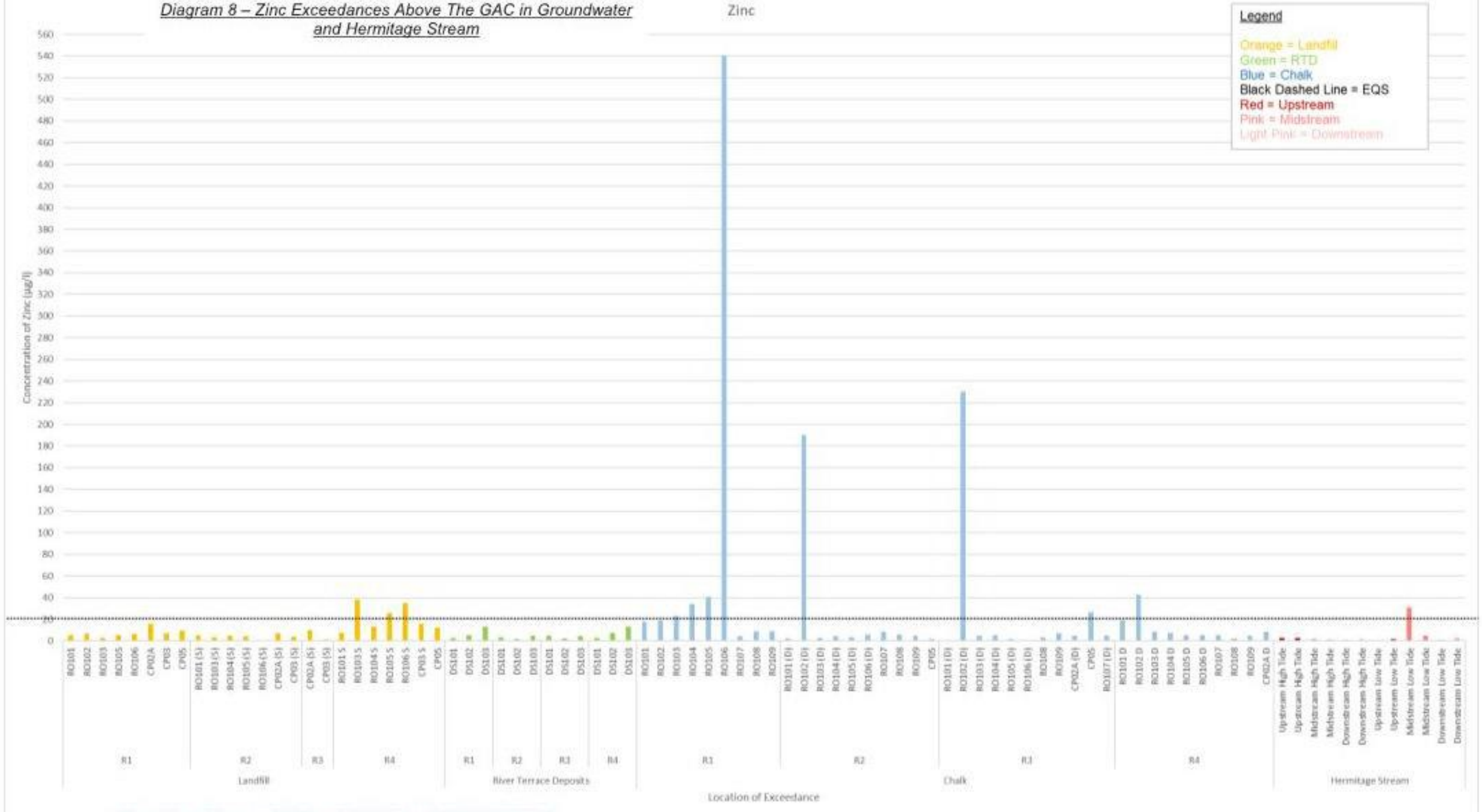
Zinc was detected above the GAC across the Site, the graph below shows the zinc concentrations for each location, split into the landfill waste, Chalk and the Hermitage Stream.

Zinc concentrations were identified to be significantly higher (orders of magnitude) within the Chalk compared to the landfill waste samples , suggesting the data may be representative of an off-Site source. Only one of twelve surface water samples recorded zinc above the GAC from the midstream point following a period of dry weather (Round 1 of 2 only).

Notably, the midstream sample collected following a moderate rainfall event did not record an elevated concentration of zinc, despite increased rainfall infiltration likely mobilising and transporting leachate at a greater speed.

Based on the limited elevations within the Hermitage Stream and, the significantly greater concentrations within the Chalk indicating a potential off-Site source, the risk associated with the Site, contributing to elevated concentrations of zinc within the stream, is considered to be low.

Diagram 8 – Zinc Exceedances Above The GAC in Groundwater and Hermitage Stream



Inorganics

A number of inorganic contaminants (ammoniacal nitrogen, nitrate, nitrite and total phenols) have been detected in groundwater samples at concentrations exceeding their adopted GAC. These are typical components of landfill leachate, indicating that groundwater underlying the Site appears to be generally impacted by the landfill, which is to be anticipated given that groundwater below the Site is in contact with the waste mass since placement of waste materials within the Site pre-dated the requirement for engineered containment.

An assessment of the monitoring data indicates the following:

- Nitrate and nitrite concentrations were not recorded at concentrations above the GAC within the landfill leachate. Total nitrogen concentrations are not observed to vary significantly within the Hermitage Stream upstream / downstream, with no evidence of impact from the Site associated with nitrogen species (albeit note comments below regarding ammoniacal nitrogen)–;
- Whilst chloride concentrations were detected above the GAC across the Site in all strata the Site, based on existing data presented above, is subject to saline intrusion and is therefore fully anticipated to be elevated; and
- There were no clear trends in contaminant concentrations during the duration of the monitoring programme.

The most notable exceedance of the adopted GAC was for ammoniacal nitrogen; groundwater samples recovered from the landfill waste exhibited concentrations typically two to three orders of magnitude above the GAC.

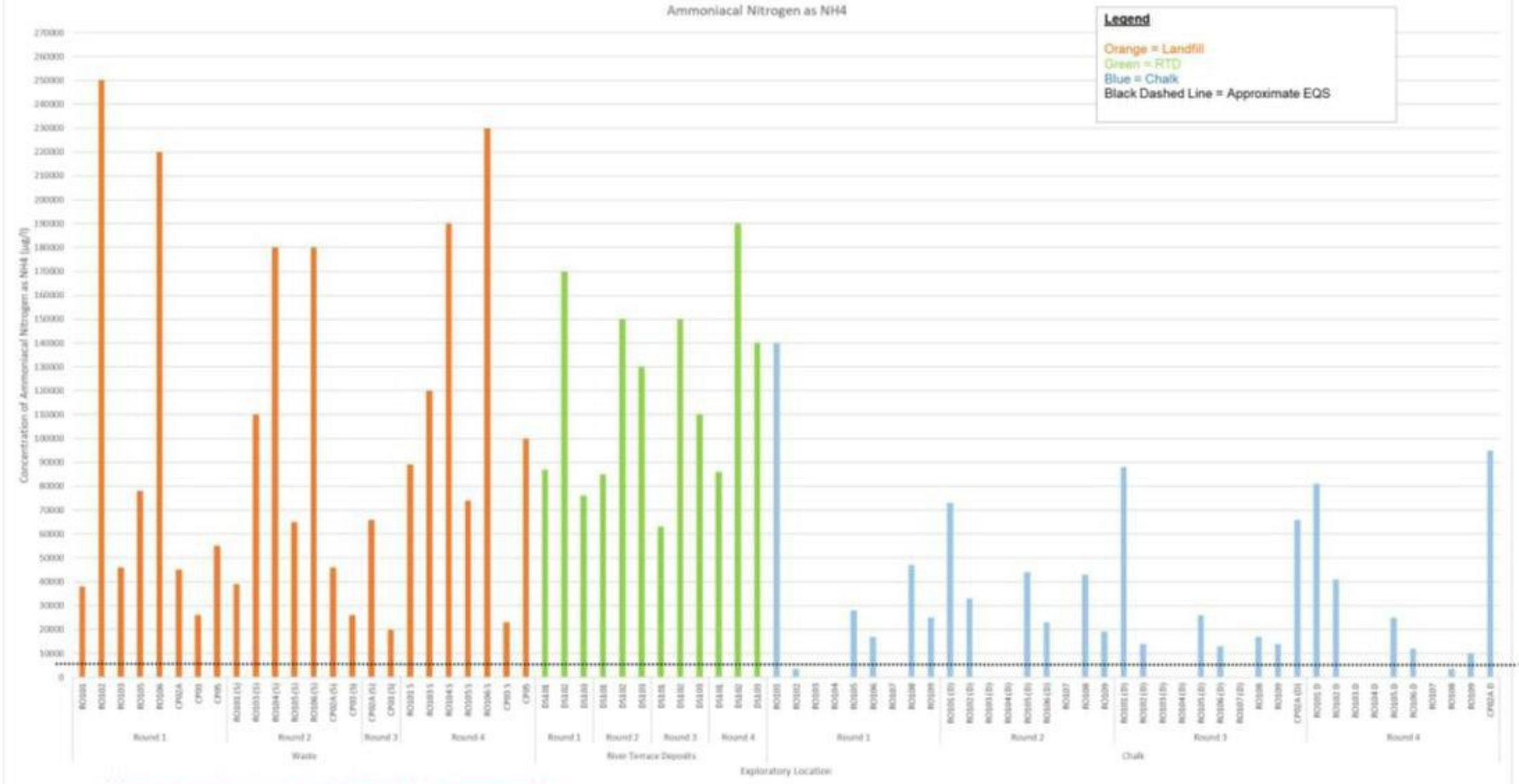
The principal receptor for this assessment is the Hermitage Stream and Langstone Harbour which the stream flows into. As such, the main contaminant of concern with regard to ammoniacal nitrogen would be ammonia (NH3); which, due to it removing dissolved oxygen from water, is considered to be toxic to aquatic life.

Delta-Simons calculated the ammonia content from the total ammoniacal nitrogen, pH and temperature. The percentage of NH3 versus ammonium (NH4) ranged between 0.11 and 1.68%. Therefore, it is considered that the ammoniacal nitrogen is mostly in the form of NH4. The ammoniacal nitrogen data is included within Appendix F.

The calculated NH3 values were compared against the respective surface water GAC and three locations presented concentrations marginally above the GAC of 300 µg/l. The maximum concentration (405.5 µg/l) was encountered within the landfill waste but did not correspond with any elevated concentrations within the Chalk. Elevated concentrations of NH3 above the adopted GAC were only encountered on one occasion for the three monitoring wells (these had response zones constructed in the waste mass and there were no elevated results within the Chalk. Additionally, NH3 concentrations were not detected above the GAC within the Hermitage Stream samples.

NH4 concentrations were detected at concentrations significantly higher than the GAC across the Site. The graph below displays the NH4 exceedances split into each lithology.

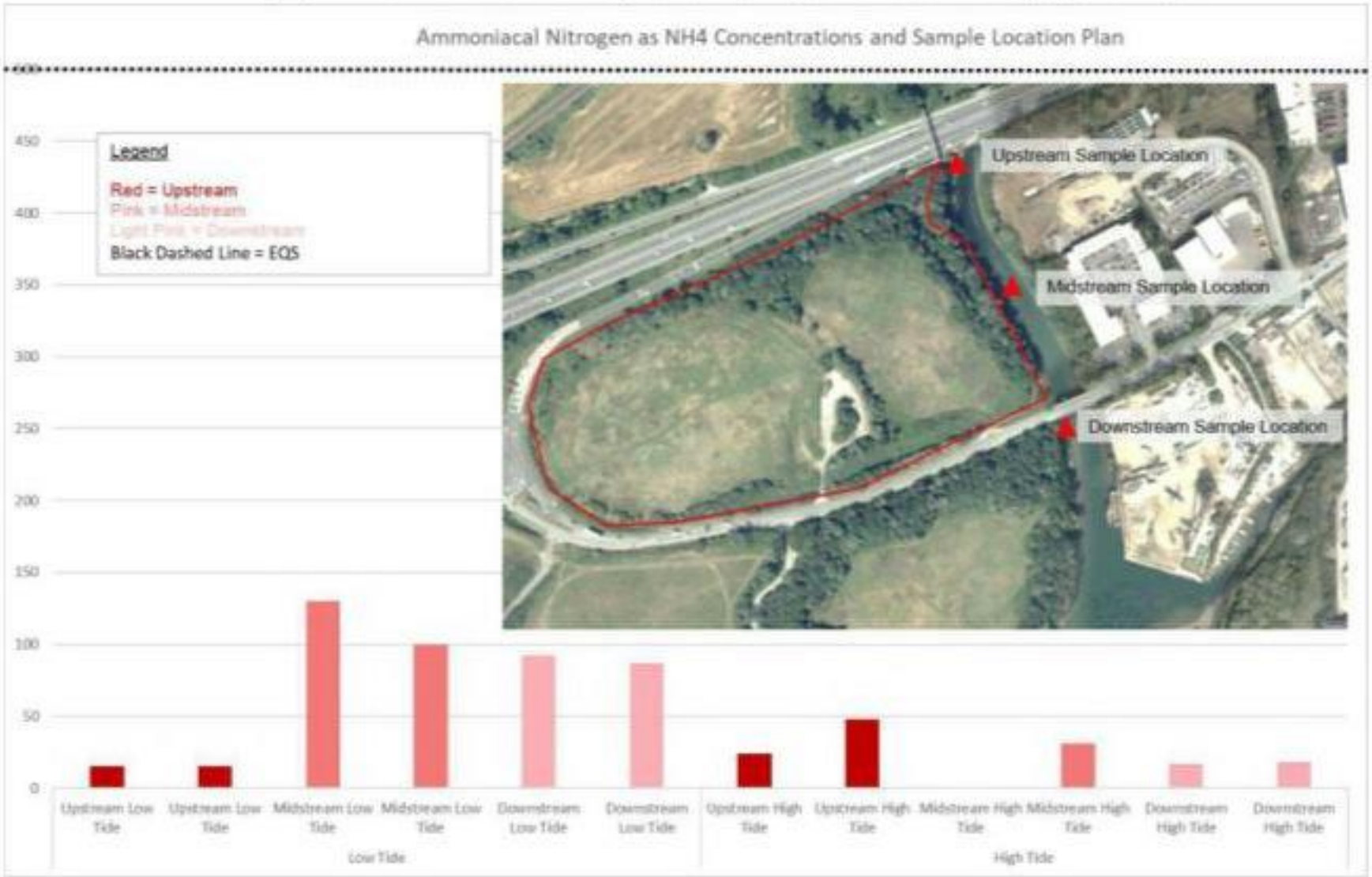
Diagram 9 – Ammoniacal Nitrogen as NH4 Concentrations in Groundwater



The concentrations of ammoniacal nitrogen as NH4 significantly decrease as the groundwater migrates downward from the landfill waste into to the RTD and then into Chalk, which is to be anticipated given the likely various contaminant attenuation processes. The maximum concentration recorded within the Chalk is almost four times lower than the maximum concentration recorded within the landfill waste.

The data provides evidence that NH4 is increasing in concentration in the Hermitage Stream at low tide at the midstream and downstream locations, suggesting a complete pollutant linkage from the landfill leachate through to the surface water receptor. However, whilst the concentration of NH4 is elevated at the midstream and downstream locations at low tide, the concentrations are a long way below the adopted EQS. This demonstrates that dilution within the stream is more than sufficient to mitigate risk of harm to the aquatic life that the EQS is designed to protect. The graph below summarises the ammoniacal nitrogen (as NH4) results recorded within the surface water samples taken from the Hermitage Stream.

Diagram 10 – Ammoniacal Nitrogen as NH4 Concentrations in Hermitage Stream



Based on the chemical data, it is considered that attenuation and/or dilution is acting at a sufficient level for both NH4 (drinking water risk driver) and NH3 (aquatic life risk driver) is only marginally above the conservative GAC on Site. The risks to controlled waters posed by ammoniacal nitrogen is therefore considered to be low.

Total nitrogen species concentrations within the Hermitage Stream do not vary significantly upstream / downstream at either high or low tide. This confirms absence of notable impact on the stream from Site-derived landfill leachate.

Polyaromatic Hydrocarbons

Concentrations of several PAHs (naphthalene, anthracene, fluoranthene, benzo[a]pyrene and benzo[b]fluoranthene) marginally above the adopted GAC were identified in several monitoring wells across the Site. However, concentrations were predominantly located within the landfill waste monitoring wells and typically exhibited reducing concentrations in the RTD to below GACs predominantly in the Chalk wells. Furthermore, these contaminants were not elevated above the limit of detection within the Hermitage Stream samples.

As such, it is considered that the concentration of PAHs within the landfill leachate are being sufficiently attenuated through the sub landfill strata and therefore, the risk is considered to be low.

Petroleum Hydrocarbons

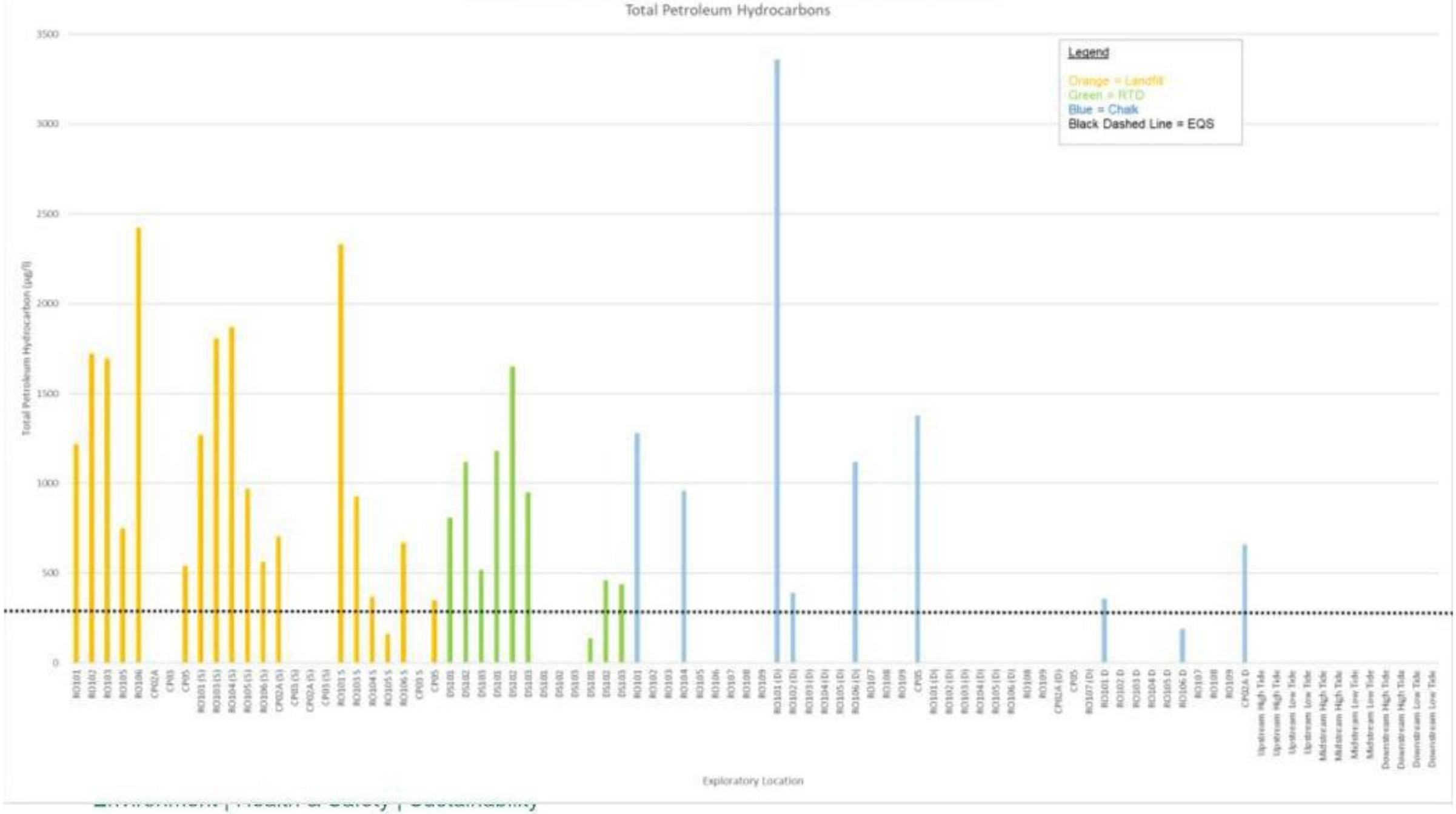
RO101 and RO103, situated in the west cell, recorded elevated concentrations of aromatic >C5-C7 and >C8-C10 as well as benzene (RO101 only) and ethylbenzene (RO103 only). These short chain hydrocarbons are of relatively high solubility and therefore potentially highly mobile, however, there is no evidence of increasing concentration as groundwater flows south / south-east laterally across the Site or, downward into the Chalk.

As such it is considered these concentrations represent localised hotspots within the landfill waste and not widespread contamination. Therefore, the risk associated with these hotspots is considered to be low.

Total petroleum hydrocarbon concentrations (TPH) were elevated above the GAC in monitoring wells installed within all lithologies across Site wide. The exceedances were highly variable across each stratum, with the maximum concentration recorded within the Chalk. This suggests that petroleum hydrocarbons are infiltrating on the Chalk aquifer.

The graph below summarises the TPH data, including all groundwater and surface water data.

Diagram 11 – TPH Concentrations in Groundwater and Hermitage Stream



Whilst the concentrations within the Chalk are elevated that are based on a conservative aliphatic hydrocarbon surrogate GAC of 300 µg/l which are exceeded by up to an order of magnitude in RO101 (Chalk) but generally concentrations are below 2,000 µg/l. There was no visual/olfactory evidence of NAPL recorded during the groundwater monitoring supporting the considered minor hydrocarbon impact on the chalk aquifer. Given that not all Chalk boreholes encountered elevated petroleum hydrocarbons it is considered that the impact on the aquifer is localised. Furthermore, no surface water samples collected from the Hermitage Stream recorded TPH concentrations above the limit of detection.

It is considered, the groundwater data demonstrates that whilst there are elevated concentrations of TPH within the landfill leachate that have migrated to the Chalk aquifer, the contamination is localised and is being sufficiently diluted through lateral groundwater flow across the Site, thereby preventing any detrimental impact on the quality of the Hermitage Stream.

Groundwater Summary

Heavy metal, inorganic and organic groundwater contamination, as a result of landfill leachate migration, has been identified across the Site within all three lithologies. However, the data has demonstrated that effective attenuation is occurring within the sub landfill strata Chalk and / or dilution effects laterally, into the Hermitage Stream where concentrations remain elevated within the Chalk aquifer (TPH, ammoniacal nitrogen [NH4], nitrite, zinc, copper and chromium) reducing concentrations below the GAC (EQS) within the stream. Further to this it is evident that not all contamination is Site derived (zinc, chloride and nitrite).

Despite the data demonstrating the effectively attenuation of contaminants in the sub landfill strata, it is also anticipated the proposed development will limit rainwater infiltration into the landfill waste mass and in turn, reduce the migration of landfill leachate into the sub surface strata and stream that is in hydraulic connectivity with these strata. Therefore, following construction of the proposed development, it is likely concentrations of contaminants (including ammonia, nitrite, TPH and zinc, copper and chromium) should reduce in the Chalk and subsequently the Hermitage Stream – as a result of the reduced infiltration and environmental betterment will be achieved (though this does not factor in any off-Site sources). Reduced infiltration associated with the proposed development is discussed further in Section 6.3.4.

Based on the demonstration of effective attenuation/dilution, potential off-Site contribution and proposed environmental betterment, the risk associated with groundwater contamination and the impact to the Hermitage Stream is considered to be low and no further action is required.

Whilst it is evident the Site poses a source of contamination and is discharging ammoniacal nitrogen into a eutrophic environment, the proposed development is considered to provide environmental betterment by virtue of the significantly increased provision of hardstanding as part of the development (and thereby reduced infiltration). Not only for the Hermitage Stream but also for the Langstone Harbour which is a site of significant ecological importance including a Natura 2000 site, Ramsar Site, a Site of Special Scientific Interest (SSSI), a Special Area of Conservation (SAC) and a Special Protection Area (SPA).

It should also be noted there is a sheet pile wall present along the eastern boundary between the Site and the Hermitage Stream. It is considered that this is acting to reduce lateral migration of leachate/impacted groundwater, and this is borne out by the results of water quality monitoring within the Hermitage Stream.

Saline Environmental Quality Standards (EQS)

For completeness, the groundwater data was also screened against the relevant saline EQS guidance for the specific analytes included within the document. The contaminant concentrations above GAC include ammoniacal nitrogen, anthracene, fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, copper, mercury, nickel, zinc, total xylene and dibenzofuran.

All of the above contaminants have been discussed previously in the report, with the exception of total xylene and dibenzofuran. An elevated xylene concentration was recorded in one borehole only on a single occasion and, as discussed within the petroleum hydrocarbons section above, this is likely to represent a localised hotspot. Additionally, such concentrations were not recorded within the surface water samples collected from the Hermitage Stream, further demonstrating this is likely represents locally impacted groundwater that does

not appear to be adversely impacting the quality of the watercourse (considered, alongside Langstone Harbour, to be the critical controlled waters receptor).

With regard to the elevated dibenzofuran concentrations, these are considered to be minimal in extent and were recorded within three locations (within the landfill waste, River Terrace Deposits and Chalk) during a single sampling round only. The elevated concentrations are not widespread and are not replicated within the watercourse therefore, they are considered to be representative of locally impacted groundwater and do not pose a risk to the quality of the Hermitage Stream.

It is considered that, when compared with the saline EQS values, the groundwater and surface water data does highlight a plausible risk to the Hermitage Stream or the Langstone Harbour.

The groundwater analysis results are considered further in the CSM presented in Section 8.0 with regard to potential contaminant linkages.

6.3.4 Rainwater Infiltration Modelling

As discussed in the section above, it is anticipated that the proposed development will limit rainfall infiltration and so, leachate migration into the Chalk aquifer and Hermitage Stream will be reduced.

Delta-Simons have undertaken an assessment to determine the existing rate and volume of infiltration at the Site which could contribute to the mobilisation of local contamination.

We have utilised the IH124 methodology to determine the level of infiltration at the Site utilising local catchment characteristics. The Institute of Hydrology carried out a number of studies on revising the runoff equations produced in the original Flood Studies Report (1975). IH124 was specifically produced to address the runoff from small catchments. (Institute of Hydrology, 1994).

The HR Wallingford IH124 calculations sheet is included as Appendix G. The SPR (standard Percentage Runoff coefficient) for the Site is identified as 0.37 meaning that 37% of the total rainfall falling on the Site is predicted to run-off, the remaining 63% will therefore infiltrate.

Table 1 presents the IH124 run-off rates for the existing site and the corresponding infiltration figures for varying return periods:

Table 1

	Greenfield Runoff Rate		Greenfield Infiltration Rate	
	l/s	m3/s	l/s	m3/s
QBAR	24.8	0.02481	42.24405	0.042244
1 in 1 year	21.1	0.02109	35.91	0.03591
1 in 30 years	57.1	0.05707	97.17324	0.097173
1 in 100 years	79.2	0.07915	134.7689	0.134769

Post development, through the introduction of hardstanding in the form of the proposed units, access service yards, car parking and the drainage infrastructure to service the Site, there will be a significant reduction in infiltration into the underlying soils post development.

The proposed hardstanding is understood to cover an area of approximately 5.132 ha with approximately 3.243 ha of soft landscaping Table 2 presents the IH124 run-off rates (taken from the HR Wallingford calculation Appendix H) for the proposed development and the corresponding infiltration figures for varying return periods:

Table 2

	Greenfield Runoff Rate		Greenfield Infiltration Rate	
	l/s	m3/s	l/s	m3/s
QBAR	9.63	0.00963	16.39703	0.016397
1 in 1 year	8.18	0.00818	13.92811	0.013928
1 in 30 years	22.2	0.02215	37.71486	0.037715
1 in 100 years	30.7	0.03072	52.30703	0.052307

The difference in infiltration pre and post development is provided in Table 3

Table 3

	Infiltration Rate		Difference Pre and Post Dev	
	Pre Dev m3/s	Post Dev m3/s	Volume m3/s	Reduction %
QBAR	0.042244	0.016397	0.025847	61
1 in 1 year	0.03591	0.013928	0.021982	61
1 in 30 years	0.097173	0.037715	0.059458	61
1 in 100 years	0.134769	0.052307	0.082462	61

Based on the above it is considered appropriate that infiltration rates into the landfill mass will be approximately reduced by around 60% against exiting infiltration

6.3.5 Light Non Aqueous Phase Liquid (LNAPL)

No LNAPL was encountered during the investigation or subsequent monitoring programme.

6.4 Built Environment

6.4.1 Potable Water Supply Pipes

The investigation requirements for the selection of potable water pipe material are set out in UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites (UKWIR, 2010). This report has very specific and onerous investigation requirements and as such the detailed investigation of each utility route was not within the scope of this investigation.

However, given the presence of organic contamination at the Site, it is considered likely/prudent to consider the use of barrier pipe materials.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy is not likely to be considered fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required at a later date once the route(s) of the supply pipe(s) are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

Should water supply pipes be entirely run through imported/reused re-engineer capping fill material the use of non-barrier pipe might be appropriate dependant on consultation with the statutory undertaker.

6.4.2 Building Materials

Risks to building materials associated with aggressive ground conditions is addressed in Section 5.9.

7.0 Bulk Ground Gas Risk Assessment

7.1 Ground Gas Conceptual Site Model

7.1.1 Sources

Historically, the Site comprised mud flats and marshland until circa early 1970s, when the Site was subjected to significant phases of household/domestic waste disposal by the local council. Landfilling ceased at the Site by circa 1987 and the Site was briefly used as a playing fields, after which no further development has taken place.

It is understood the landfill extended beyond the Site boundary and was designed to operate as a 'dilute and disperse' system incorporating no basal/sidewall lining systems (a very common concept for landfills of this time under which egress of landfill leachate would be at rates typically considered to represent environmentally acceptable rates). Additionally, the exact lateral extents could not be defined due to restrictions in the placement trial pits/boreholes at the time of the investigation. As such, it is considered prudent to assume that that the landfill material was tipped up to the boundaries of the Site.

The ground conditions were highly variable across the Site, both in composition and proven thickness. With regard to the landfill, based on the topography of the Site and the general composition of the waste, the Site can be generally split into two landfill 'cells', the west cell and east cell, each comprising materials deposited during two distinct phases of landfilling, as outlined in Section 4.2.

The landfill waste within the east cell appeared to consist of more modern household waste items including everyday plastic items, kitchen waste, glass bottles, newspapers and books. The near surface waste (encountered within the trial pits up to 4 m bgl), appeared to have undergone very little degradation, evidenced by the recovery of intact newspapers and books and the general appearance of the items. Throughout the waste mass, the percentage and composition of the matrix varied. Delta-Simons recovered newspapers dated 1986 and WYG recorded a letter dated 1982.

The west cell generally comprised less common household items and notably more 'industrial' items including large tyres, wood, metal and large-scale deposits of metal baby-powder containers. No 'black bag' waste or fully intact newspapers etc. were encountered within the west cell however, this could be indicative or predominantly domestic ashes/cinders waste streams being disposed of in the early to mid-1970s. The west cell also sits significantly lower than the east cell, which, along with the differences in waste types, supports the idea of two separate waste cells with differing dates of deposition.

Based on the forensic logging results, the percentage of putrescible material within the landfill waste in the east cell ranges between 2.1 to 19.6 % and 0 to 10.5% in the west, though it should be noted that a total of 10 samples were taken across the Site and the landfill waste is generally considered to be highly heterogenous. Any biodegradable material within the landfill has the potential to generate hazardous ground gases and is considered to be the principal source of hazardous ground gases (notably methane and carbon dioxide) on-Site.

7.1.2 Pathways

The most significant pathways with respect to future Site users relate to the potential vertical migration of hazardous ground gases and subsequent ingress into future infrastructure via service entry points and/or cracks within floor slabs.

Given the prevailing ground conditions, a piled foundation solution is anticipated as being required (see Section 5.2); theoretically, such foundations have the potential to pose a preferential migration pathway for hazardous ground gases through pressure driven flow along the pile/waste interface. This will need to be assessed as part of a specific piling risk assessment and mitigated accordingly within the Remediation Strategy.

Ground gases could also migrate laterally through granular Made Ground and granular (permeable) superficial deposits (both on and off-Site) to off-Site receptors, in the gaseous phase (under both advective [pressure driven] and diffusive [migration along a concentration gradient] flow) and/or gas within the dissolved phase via groundwater flow. Following re-development of the Site, there is the potential for lateral gas migration to be

promoted as a consequence of low permeability hardstanding preventing the escape of any hazardous ground gases that previously passively diffused to atmosphere, although areas of cohesive re-engineered cover system material are considered likely to inhibit both vertical and lateral migration of landfill gas on and off-Site.

The nearest off-Site receptors for consideration include residential housing approximately 410 m north and 1 km west of the Site, a small building within a boatyard circa 200 m south of the Site and Basepoint Business Centre approximately 75 m east of the Site.

Potential risks to off-Site receptors to the east of the Site are mitigated by the presence of the Hermitage Stream, which is considered to effectively break lateral migration pathways in an easterly direction by effectively acting as a large vent trench.

The residential housing in the north and west is not considered to be within especially close proximity to the Site and is situated either at a higher elevation (in the north) or a very similar elevation (in the west) to the Site. As such, it is considered the topography and the lateral distance would limit any significant ground gas migration to these off Site receptors.

The small building south of the Site is founded upon the wider historical landfill and so, it is not considered the Site represents any additional risk to the off Site receptor in the south.

The risk to off Site receptors is therefore considered to be low.

It is important to consider pathways for potential ground gas migration from potential sources of ground gas to sensitive receptors e.g. inhabited/occupied buildings. The most significant pathways with respect to future users relate to the potential for gases to enter the proposed building. Consequently, ingress into the building may be possible through voids in the floor including service entry points and cracks that may occur in the future.

Future maintenance/construction workers may come into contact with hazardous ground gases via entry into below ground confined spaces such as excavations or service entries/inspection points. In the context of the Site conceptual model and proposed development, it is considered that such risks can be mitigated by appropriate H&S precautions, including PPE, risk assessments and appropriate working practices.

7.1.3 Receptors

The principal receptors under consideration are future Site users and the potential exposure to hazardous ground gases migrating to the surface and into future buildings.

Other receptors include the proposed building, infrastructure and utilities which are considered to be at risk to potential hazardous ground gases that could migrate vertically to surface below the development.

Construction and ground workers are considered to be a potential receptor as landfill gas has the potential to pose both explosive and asphyxiant risks where it is able to accumulate within enclosed spaces and / or temporary excavations.

Beyond this, there are not considered to be any laterally affected receptors given the Site is bound by the A27, greenfield areas and the Hermitage Stream.

7.2 Duration & Extent of Monitoring

Tables 5.5a and 5.5b within CIRIA C665 detail current recommended monitoring duration and frequency for sites in the UK. Based on the identification of potential sources in the preceding section, the gas generation potential is considered to be high, whilst the sensitivity of the proposed development is low. On this basis, CIRIA C665 recommends a minimum of 12 visits over a minimum period of six months.

In order to reduce monitoring timescales and provide a more robust ground gas dataset, continuous gas monitors were deployed to Site and provided data every 60 mins over approximately eight weeks across a number of the boreholes. The continuous monitoring was also undertaken in conjunction with conventional spot monitoring from the 22nd March 2021 to 20th May 2021 (approximately two months duration).

The following specific ground gas monitoring events were undertaken:

- 22nd March to 23rd March 2021 – Spot Monitoring (RO101(S) to RO106(S), RO107 to RO109, DS101 to DS103, CP02A (S), CP02A(D), CP03(S), CP03(D) and CP05(S);
- 23rd March to 20th April 2021 – Continuous Monitoring (RO104, RO105 and RO106 targeting the landfill waste - Gas Sentinel®);
- 23rd March 2021 – Spot Monitoring by GGS as part of the continuous monitoring works (RO101 to RO106 targeting the landfill waste);
- 20th April 2021 – Spot Monitoring (RO101(S) to RO106(S), RO107 to RO109, DS101 to DS103, CP02A (S), CP02A(D), CP03(S), CP03(D) and CP05(S);
- 20th April 2021 to 29th April 2021 – Continuous Monitoring (RO101, RO102 and RO103 targeting the landfill waste - Gas Clam®);
- 20th April 2021 – Spot Monitoring by GGS as part of the continuous monitoring works (RO101 to RO106 targeting the landfill waste);
- 29th April to 19th May 2021 – Continuous Monitoring (RO101, RO102, RO103 targeting the landfill waste - Gas Sentinel®);
- 29th April to 19th May 2021 – Continuous Monitoring (RO104, RO105 and RO106 targeting the landfill waste - Gas Clam®); and
- 4th May – Spot Monitoring (RO107 to RO109, CP02A (S), CP02A(D), CP03(S), CP03(D) and CP05(S). RO101 to RO106 could not be accessed due to the continuous monitoring equipment installed in these locations.

The locations of the monitoring wells are highlighted on Figure 1 and indicate representative coverage across the whole study area which is within the boundary of the former landfill.

Purge and Recovery Tests (PRTs) were also conducted by Ground Gas Solutions Limited (GGS) on 20th April 2021 in four monitoring well locations (RO101, RO103, RO104 and RO106).The GGS PRT® testing involves purging a borehole with nitrogen before monitoring commences, and allowing the recharge of ground gases into the monitoring well to be recorded, thus providing an indication of the rate of flux of ground gases between the ground and the monitoring well i.e. an indication of the rate of gas entering the purged well void.

Typically, a slow recovery indicates low gas generation rates or the presence of a low pressure 'reservoir' of ground gases. Conversely, rapid recovery can either indicate high generation rates or the presence of a pressurised 'reservoir' of gases held within the pore spacing and voids of the vadose (unsaturated) zone, which immediately refills the borehole space after purging.

This can also be affected by the permeability of the surrounding geology, with highly permeable ground surrounding a monitoring well allowing faster gas recovery than a less permeable media such as cohesive soils or well degraded waste materials.

Additionally, WYG undertook six ground gas monitoring visits over five and a half weeks as part of their investigation. The following ground gas monitoring was undertaken by WYG:

- 18th May 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10);
- 25th May 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10);
- 2nd June 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10);
- 8th June 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10);
- 15th June 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10); and

- 27th June 2017 – Spot Monitoring (CP01(S), CP01(D), CP02(S), CP02(D), CP03(S), CP03(D), CP04, CP05, CP06 and WS01 to WS10).

The monitoring completed at the Site is considered to at least meet the recommended frequency and duration requirements detailed in CIRIA C665, with the additional GGS PRT® and continuous gas monitoring providing further data by which the Site's ground gas regime can be appropriately and robustly characterised.

7.3 Ground Gas Risk Assessment

7.3.1 Background

Based on the proposed residential end use, the following documents have been consulted when assessing the gas regime at the site:

- CIRIA (2007), Assessing Risk Posed by Hazardous Ground Gases to Buildings (C665).
- British Standards Institute (BSI, 2015): Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings, BS:8485.

The presence of a source of hazardous gas within the ground does not necessarily indicate a risk will be present. Consideration of recorded gas flows together with source concentrations can allow an initial assessment to be made of the potential both for generation and subsequent migration of gas. A Characteristic Situation (CS) is derived from an assessment of the ground gas data and forms the basis of determining mitigation measures.

7.3.2 Flow Rates

Based on the conventional spot ground gas monitoring and the continuous ground gas monitoring deployed to Site the following comments relate to encountered flow rates:

- Generally, no significant flow rates were recorded across the Site, during the spot monitoring and continuous monitoring undertaken by both Delta-Simons and WYG. The risk assessment will therefore be driven by gas concentrations and the conceptual site model rather than significant flow rates;
- A flow rate of 31.11 l/hr was recorded by WYG in CP03 installed within the Chalk on one occasion (Round 2). However, this monitoring well was completely flooded for every monitoring visit undertaken by WYG and subsequently, Delta-Simons. As such, this result is considered to plausibly be associated with changes in the shallow groundwater levels, potentially tidally influenced, creating a "piston effect" and thus anomalous borehole 'flow' rates. On this basis the result has excluded from further assessment;
- The second highest flow rate of the dataset (6.1 l/hr) was recorded in CP02A, installed within the Chalk. Again, this monitoring well was flooded on all six of the WYG monitoring visits. Therefore, it is considered this is likely as a result of the piston effect and this result has also been excluded from the assessment;
- It is also important to note that the WYG ground gas monitoring data reviewed by Delta-Simons only included one value for flow rate. Peak flow and steady flow were not differentiated and, given the flooding of these wells the initial flow may be higher due to fluctuating groundwater levels causing the piston effect;
- The flow rates between each landfill cell were similar; overall flow rates were low to negligible. Within the monitoring wells installed in the west cell, flow varied between <0.1 and 3.1 l/hr compared to the east which ranged between <0.1 and 3.5 l/hr;
- With reference to the Time Series Graphs included within the GGS report (see Delta-Simons Factual Geo-Environmental Investigation Report), the continuous monitoring data did not show a distinct correlation between the maximum flow rate and a fall in atmospheric pressure. Negative flows generally did not correspond with rising pressure. Additionally, the highest recorded flow within the six monitoring wells (2.55 l/hr within RO102) did not occur during periods of falling pressure; and
- Based on the above, it is considered reasonable to infer from the continuous monitoring data that the observed flow rates, whilst low to negligible, maybe being driven by changes in groundwater levels, possibly also by minor atmospheric pressure ('barometric pumping') effects. This will be considered further alongside the Purge and Recovery Test data in section 7.3.8 below.

In general, flow rates on a Site-wide basis generally appear relatively low (<3.5 l/hr) for a landfill that has received biodegradable waste materials. This suggests that gas generation rates are low overall for the Site, which may be a consequence of:

- The time that has elapsed since original placement of the waste materials;
- Relatively slow degradation of wastes, as evidenced by newspapers still being intact;
- The degradation of the cellulose wastes (such as clothes and paper) known to be present within much of the landfill is not typical of other organic wastes;
- The alkaline wastes (ash) identified across the Site (soil pH range from 7.0 to 9.5) inhibiting gas generation, since alkaline materials are known to minimise the release of carbon dioxide through carbonation reactions within the waste mass; and/or;
- The relatively low proportion of degradable wastes encountered within the landfill reducing the overall reservoir of built up ground gases that can migrate by pressure or concentration driven flow mechanisms.

The low generation rates could also be, in part, the result of slow rates of cellulose decomposition. Biological attack on cellulose typically occurs at a higher rate when the degree of cellulose dispersion is greater. This could indicate that the cellulose beneath the Site is localised, which is also indicated by the ground conditions identified in the exploratory locations. For example, larger quantities of paper waste were recorded closer to the surface and typically concentrated in hotspots. In the deeper boreholes, the percentage of cellulose containing waste was significantly less and appeared to be sparser.

7.3.3 Groundwater

All of the wells installed within the Chalk were flooded, with groundwater levels ranging from 7.21 m to 9.72 m bgl. The wells installed within the waste were only partially flooded and are not considered to have an impact on the robustness of the ground gas data obtained from these locations.

It is possible that both methane and carbon dioxide concentrations within the monitoring well headspace may be being influenced by both gases coming into or out of solution in the perched groundwater, with the higher aqueous solubility of carbon dioxide (compared to methane) resulting in this gas tending to remain in the dissolved phase.

Six groundwater samples were analysed for dissolved methane. Samples were collected from CP02A, CP03 and CP05 during the third round of the monitoring programme and from RO101 to RO103 during the fourth round.

The table below summarises the results of the dissolved methane testing, the methane concentration recorded for that well during the spot monitoring and the proportion of the monitoring well flooded at the time of monitoring.

Location	Dissolved Methane Concentration (mg/l)	Steady Methane (%v/v)	Response Zone (m bgl)	Depth to Water (m bgl)
RO101 (S)	6.7	49.9	1.5 – 10.5	8.25
RO103 (S)	8.0	67.4	3.0 – 9.0	7.95
RO106 (S)	5.4	53.7	2.0 – 13.5	11.05
CP02A (S)	4.1	5.3	1.0 – 9.0	8.61
CP03 (S)	6.0	15.1	1.0 – 10.0	7.11
CP05 (S)	8.8	22.0	1.0 – 10.0	7.63

Concentrations of dissolved methane appeared to be highest in the centre of the west cell (RO103) and the central south of the west cell (CP05). The lowest concentrations also appear to be spread across the east and west cells, indicating there does not appear to be a differentiation between each landfill cell.

Generally, the concentrations of dissolved methane recorded within the groundwater are typically higher in those locations where the higher ground gas concentrations were recorded, a correlation that is to be anticipated. These results suggest that methane may be preferentially dissolving into the groundwater in the areas where the higher results were recorded (RO103, CP03 and CP05).

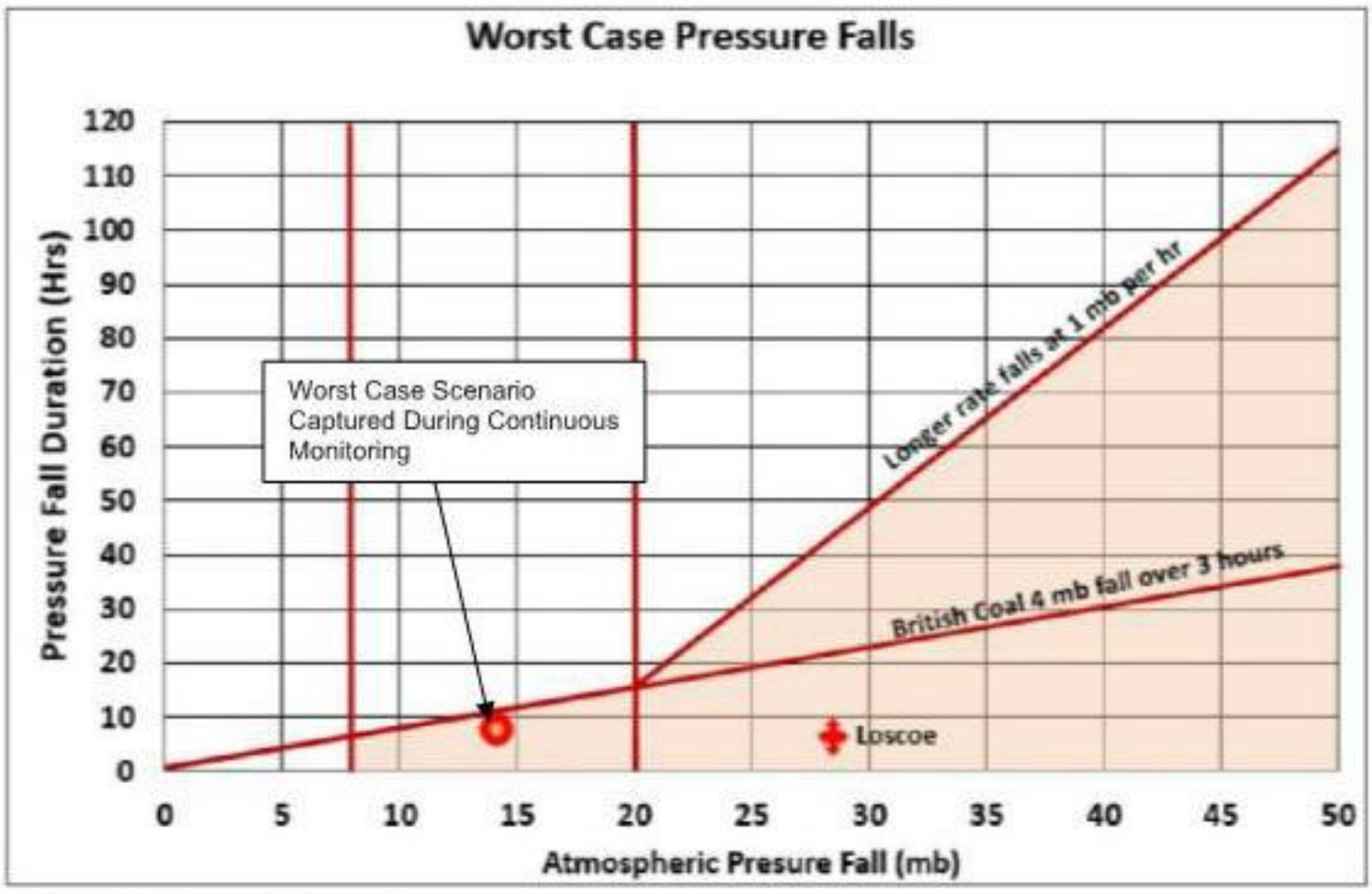
It has been established by Delta-Simons that the groundwater on-Site generally flows in a south / south-east direction. As such, the risk to off Site receptors posed by the dissolved methane concentrations within the groundwater is considered to be low, given the groundwater flows into the Hermitage Stream / Langstone Harbour and the small building circa 200 m south is already situated on the wider historical landfill.

As such, it is considered the dissolved methane concentrations do not represent a significant risk to off Site receptors and provides further evidence for elevated methane concentrations across the Site.

7.3.4 Worst Case Low Pressure/Pressure Fall Event Scenario

Based on the time series graphs produced by Ground Gas Solutions (refer to Delta-Simons Factual Geo-Environmental Investigation Report) it is evident that there appears to be no significant correlation between atmospheric pressure and gas concentrations at the Site. This included low atmospheric pressure systems and also significant atmospheric pressure falls that did not correlate to a significant increase in ground gas concentrations or flow. There also appeared to be no clear correlation between atmospheric pressure conditions and borehole differential pressures; recorded differential pressures appeared to be at, or close to, zero, indicating that where borehole flow rates have been recorded, these are likely to be as a result of changes in ground water levels &/or minor barometric pumping effects, rather than evidence of significant gas generation.

Notwithstanding this lack of correlation, it is still considered that there was sufficient low pressures systems and pressure falls to demonstrate a comparable worst-case ground gas risk scenario. This is illustrated in the graph below (refer to Delta-Simons Factual Geo-Environmental Investigation Report) which identified the Site specific pressure fall (red circle) compared to other pressure falls that have caused ground gas incidents to occur (red shaded area) for example Loscoe, Derbyshire.



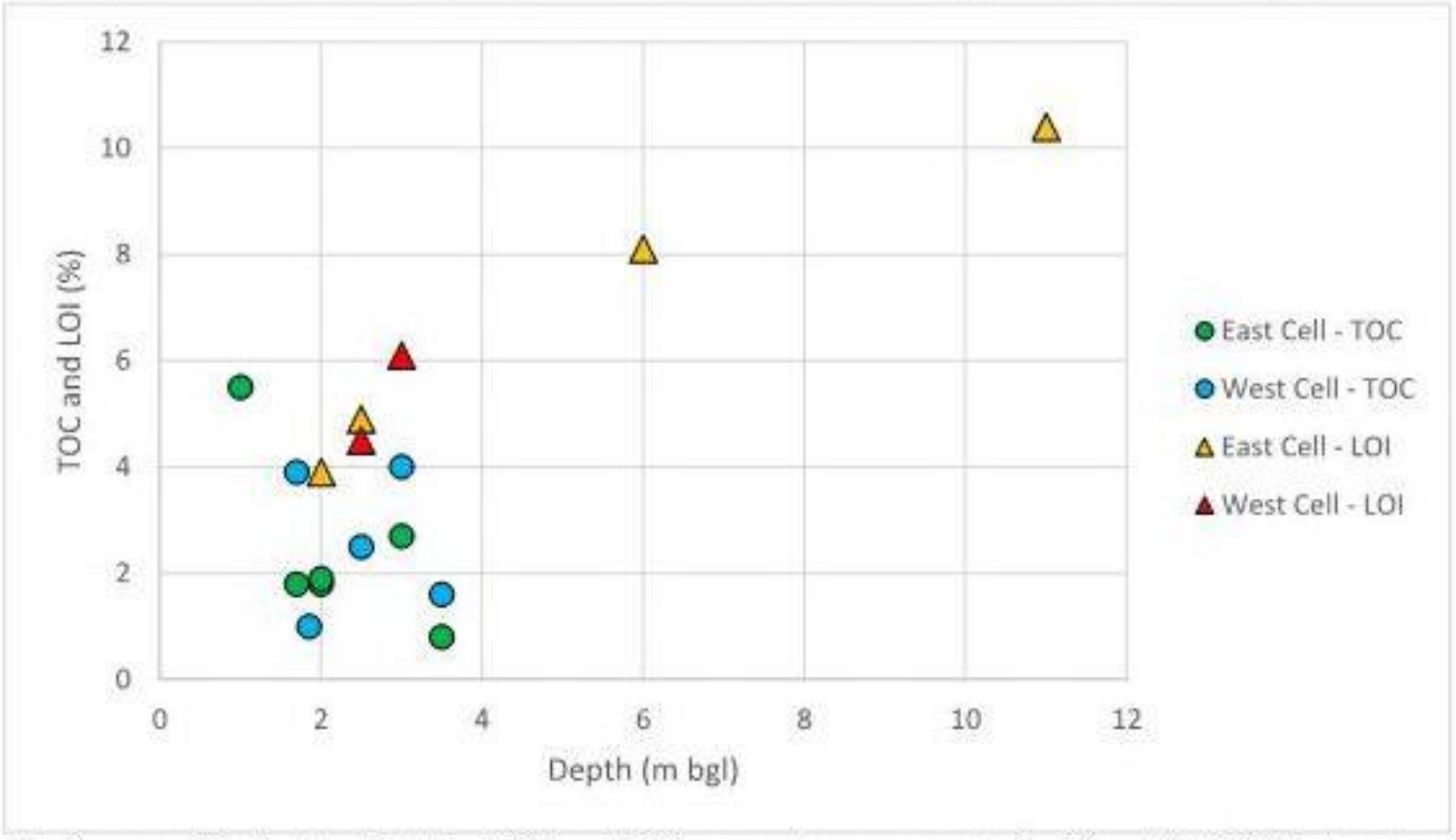
7.3.5 Biodegradable Material Content

Any biodegradable material within the landfill has the potential to generate hazardous ground gases and is considered to be the principal source of ground gas for the Site. In order to characterise the biodegradable

content within the waste and, to assess the gas generation potential of the waste mass, loss on ignition, forensic waste and total organic carbon (TOC) analysis was undertaken.

The forensic waste analysis results are summarised in Section 4.9.

The percentage of putrescible material within the landfill waste in the east cell ranged between 2.1 to 19.6 % and 0 to 10.5% in the west. These results suggest that, generally across the Site, the biodegradable content within the waste is not significant but, that there is some differentiation between the east cell and the west cell. The percentage of Loss on Ignition (LOI) and TOC has been plotted against depth on the graph below.



Generally, the graph indicates that the TOC and LOI percentages are not significant (< 12% but generally below 6% in shallow waste materials) and there is again, a small variation between the east cell and the west cell. The TOC and LOI percentages were broadly greater in the east cell but, the data highlights the landfill waste is variable both with depth and laterally.

7.3.6 Spot Monitoring and Continuous Monitoring - Gas Screening Value (GSV)

The Gas Screening Value (gas concentration as a fraction x maximum recorded flow) can be calculated using data from the spot monitoring and is used to provide an initial assessment of risks to future site users. The GSVs calculated for the monitoring wells are presented in the following table and are based upon maximum steady state concentrations and flow rates for each monitoring well.

The summary table has been split into monitoring wells installed within the east and well cell to ascertain if the age / composition of the waste is likely to be influencing gas generation potential.

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)	Strata
				Methane		Carbon Dioxide			
				GSV	CS	GSV	CS		
West Cell									
RO101 (S)	65	25.5	3.1	2.015	3	0.7905	3	0 of 5	Landfill Waste
RO101 (S)*	54.3	26.5	0.94	0.51042	2	0.2491	2	N/A	
RO102 (S)	62.8	25.1	0.4	0.2512	2	0.1004	2	0 of 5	
RO102 (S)*	64.8	26.4	2.55	1.6524	3	0.6732	2	N/A	
RO103 (S)	67.4	28	0.7	0.4718	2	0.196	2	0 of 5	

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)	Strata
				Methane		Carbon Dioxide			
				GSV	CS	GSV	CS		
RO103 (S)*	66.5	26.5	1.78	1.1837	3	0.4717	2	N/A	
CP02A (S)	5.3	8.3	-0.1	-0.0053	1+	-0.0083	1+	0 of 4	
CP05 (S)	52.1	26.3	<0.1	0.0521	1+	0.0263	1+	0 of 4	
CP01 (S)	70.6	30.1	0.3	0.2118	2	0.0903	2	0 of 6	
CP02A (S)	35.9	24.6	-0.1	-0.0359	1+	-0.0246	1+	0 of 6	
CP04	63.9	31.2	0.3	0.1917	2	0.0936	2	0 of 6	
CP05	49.6	28	0.2	0.0992	2	0.056	1+	0 of 6	
WS01	64.9	31.8	0.14	0.09086	2	0.04452	1+	0 of 6	
WS02	64.5	28.7	0	0	1+	0	1+	0 of 6	
WS03	40.8	26.2	0	0	1+	0	1+	0 of 6	
WS04	66.6	31.8	0.2	0.1332	2	0.0636	1+	0 of 6	
WS05	33	23.6	-0.1	-0.033	1+	-0.0236	1+	0 of 6	
WS06	69.6	30.7	-0.1	-0.0696	1+	-0.0307	1+	0 of 6	
WS07	98.2	29.7	0	0	1+	0	1+	0 of 6	
WS09	51.5	21	0.1	0.0515	1+	0.021	1+	0 of 3	
RO107 (D)	35	17.9	0.3	0.105	2	0.0537	1+	4 of 4	
RO108 (D)	<0.1	0.1	-0.1	-0.0001	1	-0.0001	1	4 of 4	
CP02A (D)	15.3	15.3	<0.1	0.0153	1	0.0153	1	4 of 4	Chalk
CP01 (D)	68.2	30.6	0.3	0.2046	2	0.0918	2	6 of 6	
CP02A (D)	22.5	15.3	6.1	1.3725	3	0.9333	3	6 of 6	
East Cell									
RO104 (S)	36	22.2	0.1	0.036	1+	0.0222	1+	0 of 5	
RO104 (S)*	32.2	23.2	0.09	0.02898	1+	0.02088	1+	N/A	
RO105 (S)	19.3	13.2	-0.2	-0.0386	1+	-0.0264	1+	0 of 5	
RO105 (S)*	54.8	19.0	0.16	0.08768	2	0.0304	1+	N/A	
RO106 (S)	53.7	24.6	3.5	1.8795	3	0.861	3	0 of 5	
RO106 (S)*	60.0	22.9	0.32	0.192	2	0.07328	2	N/A	Landfill Waste
CP03 (S)	48.1	27.4	0.1	0.0481	1+	0.0274	1+	0 of 4	
CP03 (S)	24.2	22.3	0	0	1+	0	1+	0 of 6	
CP06	60.1	23.2	0	0	1+	0	1+	0 of 6	
WS08	60	29.3	-0.1	-0.06	1+	-0.0293	1+	0 of 6	
WS10	46.2	18	-0.1	-0.0462	1+	-0.018	1+	0 of 6	
DS101	2.8	2.1	<0.1	0.0028	1+	0.0021	1	0 of 4	River Terrace Deposits
DS102	32.2	0.4	<0.1	0.0322	1+	0.0004	1	0 of 4	
DS103	17.4	9.3	<0.1	0.0174	1+	0.0093	1+	0 of 4	
RO109 (D)	1.1	0.5	-0.9	-0.0099	1+	-0.0045	1	4 of 4	Chalk

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)	Strata
				Methane		Carbon Dioxide			
				GSV	CS	GSV	CS		
CP03 (D)	0.1	0.6	<0.1	0.0001	1	0.0006	1	4 of 4	
CP03 (D)	24.9	21.8	31.11	7.74639	4	6.78198	4	6 of 6	

CS1
CS1+ / CS2
CS3
CS4

Notes: CPXXX = Monitoring undertaken by WYG

CS1+ = Calculated GSV is CS1; however, peak methane exceeds 1%v/v and/or peak carbon dioxide exceeds 5%v/v, therefore, consider increase in CS value.

ROXXX* = Values taken from continuous monitoring dataset

N/A = Depth to groundwater not recorded by continuous ground gas monitoring equipment

7.3.7 GGS PRT©

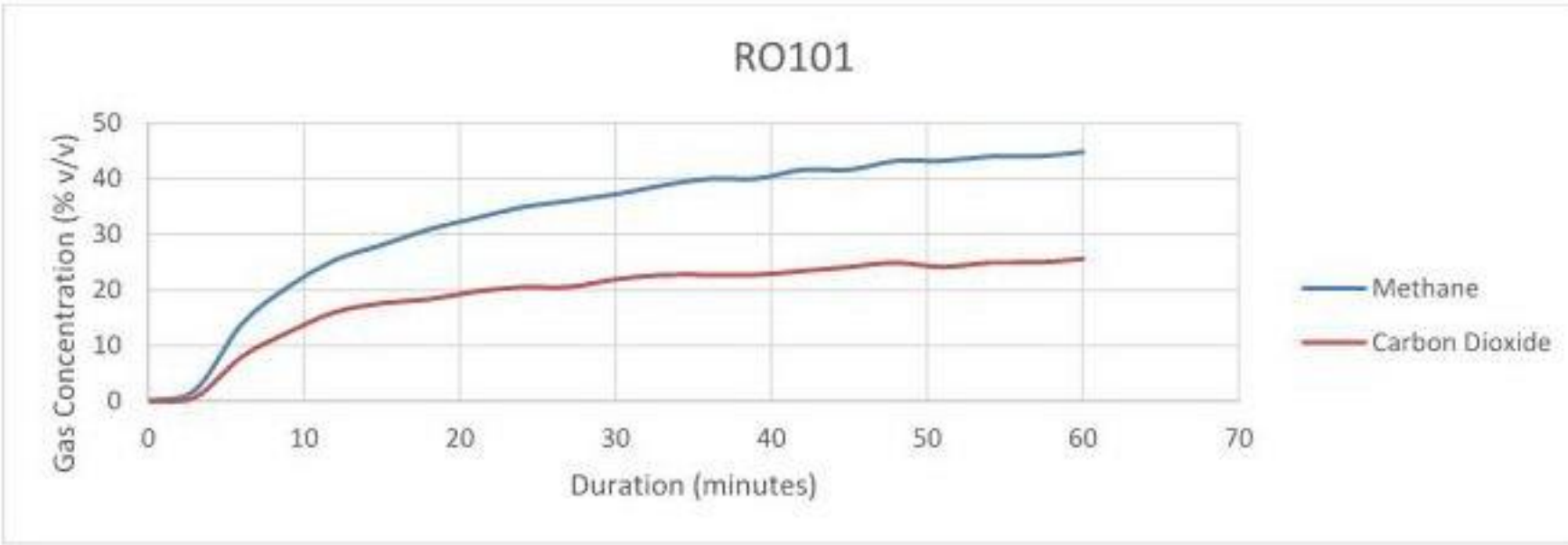
The PRTs are designed to provide a line of evidence as to the gas generation potential of the surrounding ground. They also allow further interpretation on whether gas generation is significant and if gas generation is in decline.

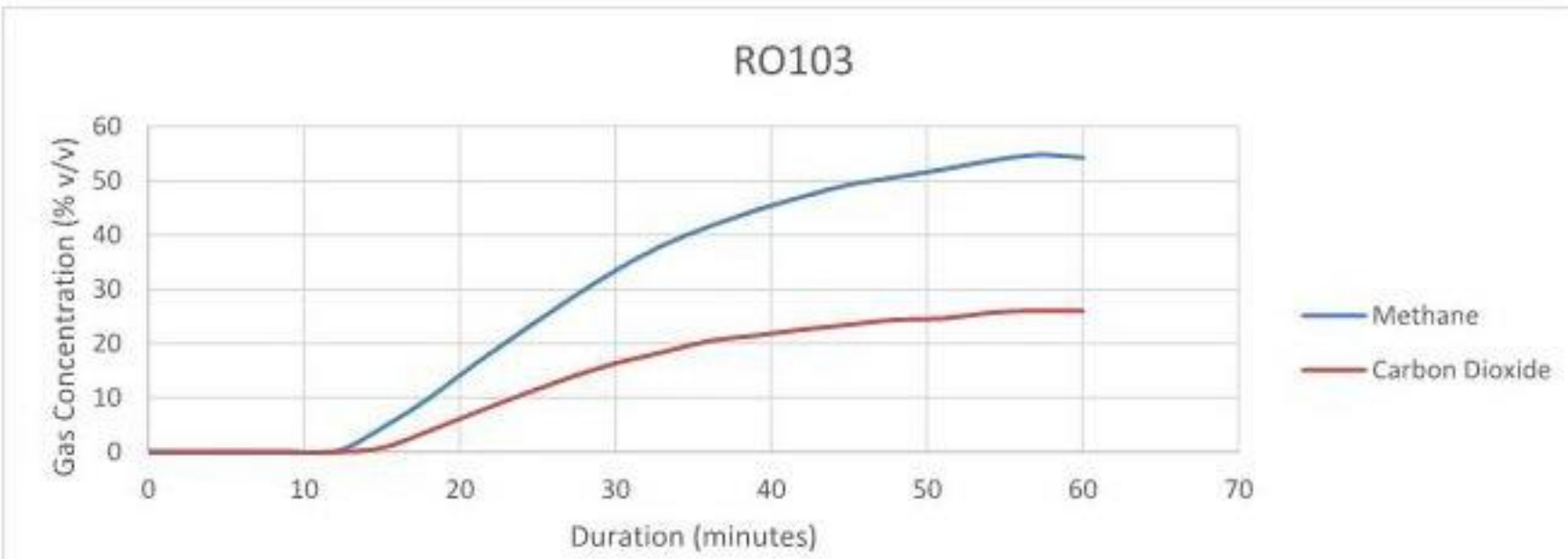
The graphs below show the concentration of methane and carbon dioxide as recorded over a 60 minute duration, for each monitoring well, following the purging of all gases to negligible levels.

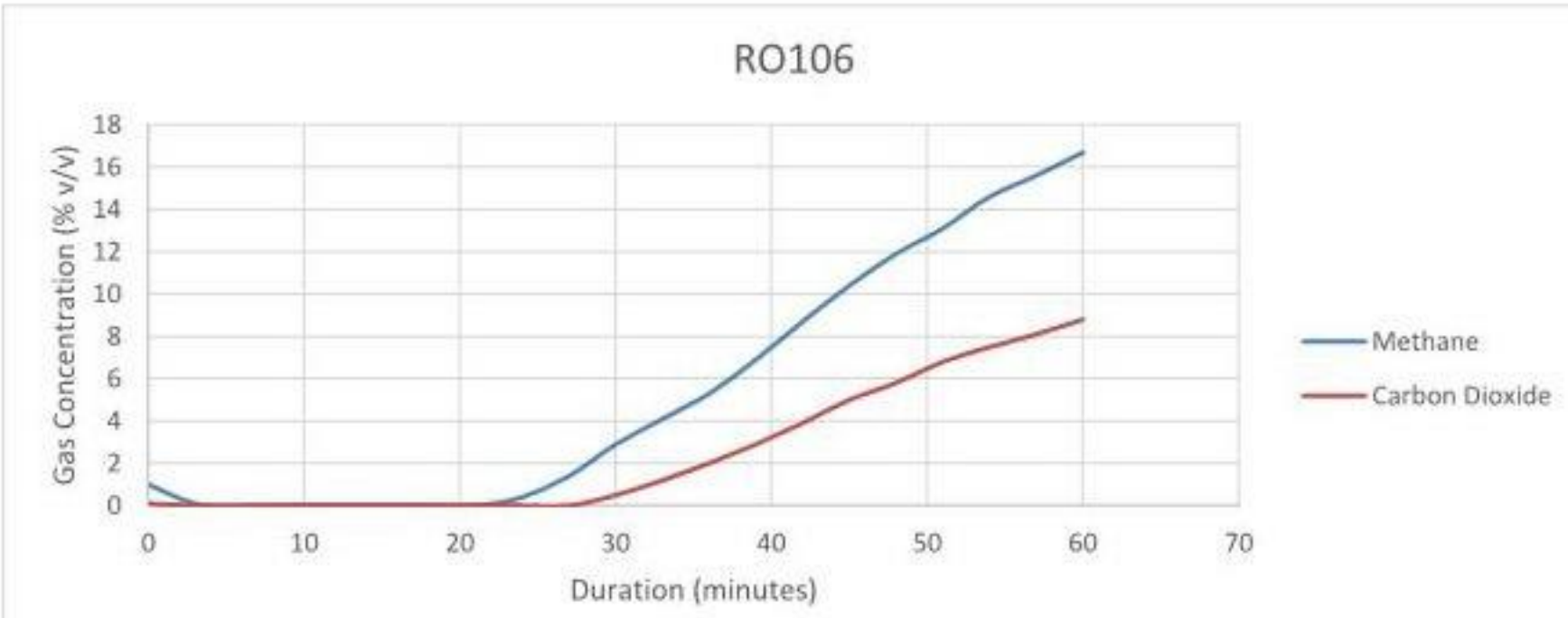
RO104 is not included in the graphs below as no significant recovery of methane or carbon dioxide was observed in the hour preceding the purging event. This, along with RO106 that recorded delayed recovery, suggests that, although active, gas generation may be low to moderate in these locations.

However, these results contrast the data recorded in RO103 and RO101; these wells showed faster recovery rates (i.e. flux of methane and carbon dioxide between the monitoring well and surrounding ground) at greater quantities (between 45 and 55%v/v of methane). This indicates gas generation potential across the Site appears to be variable. Monitoring wells RO101 and RO106 are situated in the west and east cells respectively, consequently the variations appear to be Site wide, with no apparent 'zones' of lesser risk.

Along with other lines of evidence, for example the low flow rate across the Site, these results suggest that gas generation may be starting to decline in some areas of the Site, however, there are still significant volumes of hazardous ground gas still present and generation potential remains high in some locations (RO101). The presence of un-degraded waste materials encountered during the Delta-Simons also indicates that the gas-generating potential of the waste mass may remain for some time.







Whilst the above graphs present delayed recovery and no significant recovery (RO104), the calculated methane fluxes range between 5.590 (RO106) and 9.347 (RO103). These values indicate a potentially significant gas storage potential, and thus subsequent generation potential at these locations across the Site.

This is generally in line with the high methane concentrations recorded during the continuous and spot monitoring but, does not align with the low flow rates recorded.

Additionally, the shallow landfill waste (up to 4 m bgl) in the east cell, showed little evidence of degradation, specifically in the shallower/drier materials. This again highlights the variability in landfill waste composition and gas generation potential across the Site.

7.3.8 Risk Assessment

Both spot and continuous monitoring of hazardous ground gases indicates elevated concentrations of both methane and carbon dioxide to be present on a Site-wide basis. However, flow rates across the Site appear to be low to negligible, isolated incidences of elevated rates of flow were encountered in completely flooded wells and are likely attributed to the piston effect as groundwater levels fluctuate, possibly also with minor barometric pumping effects, albeit some localised areas of higher gas generation rates may be present within the waste mass, and is to be anticipated based upon the differing ages of the deposited wastes.

Based on the data, there is considered to be a plausible risk from hazardous ground gases on the Site and protection measures will be required as part of the proposed development to adequately mitigate such risks to future Site users. These include, inter alia, ventilation systems and low permeability membranes, and these are discussed in greater detail in Section 7.4.

The data broadly indicates that the Site can be classified as CS2 and CS3 (moderate hazard potential) in accordance with BS8485:2015+A1:2019 Table 2. This is predominantly based on the majority of borehole GSVs falling into these two categories with just two boreholes (CP03(D) and RO106 (S)) being calculated as CS4. Both of these boreholes were in the east cell however CP03(D) was continually flooded and as such, the data should be treated with caution. The CS2 and CS3 classifications do not present any significant areas of the Site or differentiation between the east and west cell, that are predominantly one classification or the other but, instead, indicate the entire Site is highly variable in terms of gas generation. As such it is not considered appropriate to assign different CS levels and subsequently potentially different levels of mitigation measures within the buildings based on their position within the Site. A single and appropriately conservative CS level and subsequent mitigation measures should therefore be prescribed to all buildings on the Site.

Furthermore, the classification of the Site cannot simply be driven by the GSV, therefore, the conceptual site model along with other lines of evidence, including continuous gas monitoring and purge and recovery testing have to be taken into consideration, as part of the risk assessment.

Based on the former landfill underlying the Site, the heterogeneity of the landfill waste mass, the varying proportions of biodegradable material and the ground gas generation potential as identified from the PRT data and the continuous ground gas monitoring data being CS3 or below, a CS3 classification is considered most suitable for the Site, and risk-protective of future Site users.

Potential gas sources for a CS3 ground gas regime, as indicated by Table 8.5 of CIRIA C665, include 'old landfill, inert waste, mineworking flooded', which is considered to be consistent and appropriate based upon the conceptual model for the Site.

A GSV based on worst case gas concentrations (all boreholes on any monitoring event) x worst case (not discounted all boreholes on any monitoring event) flow is as follows:

- (98.2/100) x 3.5 = 3.437

This value is still within the range of CS3 (0.7 to <3.5)

Based on the lines of evidence discussed above this is considered to be a reasonably precautionary classification which will require appropriate ground gas mitigation and verification discussed in the following section.

7.4 Ground Gas Risk Mitigation

The ground gas regime at the Site has been classified as CS3. BS:8485 provides a scoring system to determine the appropriate protection measures for a proposed development in accordance with the identified ground gas regime. Table 3 of BS:8485 summarises typical UK building types, which for this development will comprise Type C (Commercial Office / Retail). Table 4 details the points required for the Characteristic Situation for such a development type, which for CS3 is 3. This can be achieved by a combination of two or more of the following:

- Structural barriers (Table 5 BS:8485)
- Ventilation (Table 6 BS:8485)
- Gas Membrane (Table 7 BS:8485)

The above should be considered in conjunction with the proposed foundation/floor slab design to achieve the minimum score required within BS:8485. Based on the proposed piled foundation solution and suspended floor it is likely that at least 1.5 of these points can be attained by a suitably ventilated sub floor void.

Specific details of the mitigation measures should be considered after consultation with the structural engineers and included within the Remediation Strategy for the Site.

Given the CS3 classification the installation and verification of gas protection measures should be in compliance with CIRIA C735 *Good Practice on the Testing and Verification of Protection Systems for Buildings Against Hazardous Ground Gases* (2014)

7.5 Radon

The Site is located within an area where radon protective measures are not required.

7.6 Organic Vapours

Sources of volatile vapours have not been identified at the Site.

8.0 Revised Conceptual Site Model

A revised CSM is presented in the table below, and has been formulated taking into account all of the available data from the Delta-Simons and WYG intrusive investigation, suitable for a Site with a proposed commercial end-use.

Revised Conceptual Site Model				
Source	**Pathways**	**Receptors**	**Confirmed Risk?**	**Mitigation**
Historical Landfill	Ingestion and/or inhalation of soil/dust	Human health – site users	Yes	Asbestos was detected within the re-engineered cover system and landfill waste. As such, these soils would not be suitable for landscaping purposes on the re-developed Site. A suitable thickness of verified clean cover soils will be required in any areas of soft landscaping that are directly underlain by the existing re-engineered cover system or landfill waste. As there were no asbestos detects within the existing topsoil across the Site, it is considered that, subject to careful segregation / storage and further testing, this material should be suitable for reuse within the clean cover system. There were no other exceedances when soil determinants are screened against commercial GAC criteria, and contaminant concentrations reported in soils are not considered to represent a significant risk to human health in the context of risk to future construction workers or operational Site personnel. Short term risks to construction and groundworkers would be mitigated by use of PPE, appropriate risk assessments/method statements & provision of suitable welfare facilities. Potential risks from fugitive dusts generated by Site soils/waste materials can be mitigated by a Construction Environmental Management Plan that includes the appropriate use of dust suppression systems.
		Human health – construction workers	Yes	
	Migration of contaminants into groundwater (TPH, ammoniacal nitrogen [NH4], nitrite, zinc, chromium and copper)	Principal Aquifer (Chalk)	No	In the context of the proposed development, and surrounding area, there is not considered to be a significant risk to Controlled Waters receptors warranting further assessment or remedial action. Whilst the groundwater within the Chalk aquifer below the Site appears to be impacted to some extent there is evidence that these

	Migration of contaminants into surface waters	Hermitage Stream and Langstone Harbour		contaminants are naturally attenuating in the sub landfill strata. Further to this there is evidence that certain contaminants (zinc, chloride and nitrite) are likely be attributable, at least in part, as a result of off-Site sources. There is also evidence to suggest that the concentrations of the elevated contaminants of concern are below the GAC (EQS) values within the stream This report has also demonstrated that the proposed development will significantly reduce infiltration into the waste mass compared to existing conditions, resulting in overall betterment through a reduced mobilisation of contaminants from the waste mass to groundwater and thence the Hermitage Stream and Langstone Harbour beyond (considered to be the critical controlled waters receptor).
Historical Landfill - Ground gases and dissolved methane	Indoor exposure via enclosed space accumulation of gas	Buildings and site end users	Yes	Gas protection measures in line with CS3 are recommended to mitigate the risk of ingress of gas into the proposed building.
		Off Site receptors	No	The risk to off Site receptors is considered to be mitigated by the presence of the Hermitage Stream, sufficiently acting as a large vent trench, for ground gas migration eastwards. The residential properties to the north and west are considered to be a sufficient distance from the Site to mitigate any risk associated with lateral migration and the small building circa 200 m south is also situated upon the former historical landfill – so no additional risk is considered to be posed by the Site.
Piling through the Historical Landfill	Preferential migration of contaminants into groundwater	Principal Aquifer (Chalk)	?	A Foundations Works / Piling Risk Assessment will need undertaken to assess risks to the proposed buildings (ground gases) and to the stream/Langstone Harbour (preferential pathways for leachate). This risk assessment will need to consider how these risks will be mitigated during any piling, ground improvement and constriction phases of the development.
	Preferential migration of ground gases resulting in accumulation of gas in enclosed space	Buildings and site end users	?	

9.0 Conclusions & Recommendations

9.1 Geotechnical Summary

It is understood that earthworks will be required as part of the proposed development, which will include the re-use of existing Made Ground soils in a significant Site wide cut and fill operation. These works need to be coordinated with the ground improvement specification and methodology adopted for the Site.

Based on levels provided in Drawing 3, current Site levels are highest in the eastern area of the Site, at approximately 14.0 m AOD. In the western area of the Site, levels typically range between 10.5 – 11.0 m AOD.

In order to limit settlement cover the lifetime of the development a ground improvement solution is recommended across external areas of the Site to prevent damage to drainage runs etc. and mitigate the potential for differential settlements between external areas, piled buildings, and landfill boundaries.

It is recommended that a ground improvement specialist is consulted to design a suitable solution at the Site, taking into consideration the proposed elevations and landfill thicknesses requiring treatment, environmental constraints and programme.

A piled foundation and slab solution using pre-cast concrete driven piles transferring loads to competent Chalk geology may be suitable for the expected design loads, utilising both skin friction and end bearing capacity.

The precise method of pile installation and applicability of proprietary systems, diameters and depths required would need to be informed based on the results of this investigation, by discussions with a piling contractor with suitable experience in Chalk.

A preliminary CBR value of 1% can be assumed for the ground model in its current form, however, is likely to be highly variable due to the compressibility of the ground model.

Design Sulphate Class DS-3 and ACEC Class AC-3 for soils and groundwater, when considering the most appropriate type of concrete to be used at the site in order to resist chemical attack from elevated sulphate present in the soils (assuming mobile groundwater in potentially pyritic soils).

However, the groundwater data suggests that the concentrations of ammonium (predominantly the perched groundwater within the landfill waste and River Terrace Deposits) present 'highly aggressive' conditions with regard to buried concrete and the guidance suggests that specialist advice should be sought in this instance.

9.2 Contamination Issues

The investigation has been carried out in order to provide information on the quality of the soil and groundwater beneath the Site in the context of land contamination and provide information on the ground gas regime beneath the Site for a commercial end use. The assessment is being completed prior to the proposed redevelopment of the Site.

9.2.1 Human Health

Asbestos was detected within the re-engineered cover system and the landfill waste. In general, potential health risks from shallow impacted soils can be mitigated via the presence of buildings and hardstanding, which will satisfactorily address direct contact exposure pathways. In areas of proposed soft landscaping it is recommended that a cover layer system of clean soils (either imported or reused existing topsoils where fully characterised) where Site re-engineered cover system materials or landfill wastes are likely to be exposed at surface on the re-developed Site, to mitigate potential health risks to future Site users. The final design of such a system will be subject to regulatory approval.

Potential health risks from asbestos fibres can be mitigated by the presence of buildings, hardstanding and clean cover soils in areas of soft landscaping. The presence of asbestos-impacted soils at shallow depth should be recorded in the Site's Asbestos Management Plan.

There are no other exceedances when soil determinants are screened against commercial GAC criteria, and contaminant concentrations reported in soils are not considered to represent a significant risk to human health in the context of risk to future construction workers or operational Site personnel. However, further sampling and analysis of any soils to be reused in the proposed landscaping will be required to adequately characterised as part of the clean cover.

Groundworkers and sub-surface maintenance workers should be made aware of the possibility of encountering contaminated soils through toolbox talks and in particular the potential presence of asbestos and an appropriate protocol to mitigate exposure of the workforce and general public should be in place. The Contractor will need to prepare a risk assessment which identifies a safe system of work to handle the asbestos containing soils which is likely to include asbestos awareness training, a protocol for unexpected finds (should gross asbestos material be identified) as well as safe working procedures such as damping down of excavations and stockpiles in line with general dust generation mitigation. The risk assessment will need to identify the appropriate levels of PPE and/or RPE required. This recommendation should be captured in Site health and safety documentation and in maintenance plans.

Should bulk asbestos be encountered during any groundworks, works should cease until an appropriate assessment and management plan under CAR 2012 has been undertaken.

9.2.2 Controlled Waters

Groundwater below the Site appears to have been impacted as a consequence of the landfilling operations, which is to be anticipated given landfilling occurring prior to any requirement for engineered containment.

Groundwater contamination, as a result of landfill leachate migration, has been identified across the Site within the Chalk aquifer. However, the data has demonstrated that not all contamination is Site derived and, notably that natural attenuation is likely to be occurring in the sub landfill strata / Chalk aquifer corresponding to concentrations within the stream below EQS values.

Whilst it is evident is that the Site is likely to be discharging ammoniacal nitrogen into a eutrophic environment albeit at concentrations within the stream that are below the EQS. However, the proposed development is considered to provide environmental betterment by virtue of limiting rainfall infiltration into the waste mass thereby limiting leachate mobilisation and migration to off-Site sensitive receptors. This would apply not only for the Hermitage Stream but also for the Langstone Harbour which is a site of significant ecological importance including a Natura 2000 site, Ramsar Site, a Site of Special Scientific Interest (SSSI), a Special Area of Conservation (SAC) and a Special Protection Area (SPA).

9.2.3 Ground Gas

Monitoring of hazardous ground gases indicates elevated concentrations of both methane and carbon dioxide to be present on a Site-wide basis. Based on the data obtained to date, there is considered to be a plausible risk from hazardous ground gases on the Site; protection measures will be required as part of the proposed development to adequately mitigate such risks to future Site users.

Potential risks to off-Site receptors to the east are mitigated by the presence of the Hermitage Stream and there are no buildings within 200 m of the Site which would be at risk from further induced lateral migration of ground gases as a result of significant hard standing within the proposed development.

Ground gas monitoring indicates the Site can be classified as CS3. On analysis of the data, with maximum steady carbon dioxide and methane readings of 31.8 % and 98.2 % respectively albeit with generally low flow readings, it is considered prudent to adopt gas protection measures in line with CS3 as a precautionary approach across the Site.

9.3 Recommendations for Supplementary Work

Based on the findings of this report, the following recommendations for supplementary works are made;

- Preparation of a Remediation Strategy, to mitigate any unacceptable risks specifically in relation to ground gas mitigation but also including clean cover in landscaped areas. This Strategy is likely to be required to support the discharge of relevant planning conditions that are likely to be imposed;

- The re-use of materials on-site (soils and re-engineered cover system) may be possible where the material is chemically and geotechnically suitable for its proposed end location. Material re-use would need to be undertaken under a Materials Management Plan. Any imported material, including topsoil would also be chemically and geotechnical suitable for its proposed end-use;
- Preparation of a Piling / Foundations Works Risk Assessment to ensure risks to sensitive receptors, principally gas migration risk from piles and mobilisation of contaminants from the piling, ground improvement and construction phase of the development;
- Detailed slope stability assessments, inclusive of additional supportive ground investigation are likely to be required for bunds A – AA and B – BB;
- Guidance should be sought from a specialist regarding the risk to buried concrete and the ammonium concentrations within the groundwater; and
- Further testing of the existing topsoil across the Site to ensure it is suitable for reuse within the clean cover system.

Drawing 1 – Site Layout Plan, Harts Farm Way, Havant by Michael Sparks Associates (Ref: 31383/FE/37)

NOTES:

SUBJECT TO STATUTORY CONSENTS

SUBJECT TO SURVEY

BASED ON OS MAP REPRODUCED BY PERMISSION OF CONTROLLER OF HM STATIONARY OFFICE (c) CROWN COPYRIGHT

COPYRIGHT RESERVED

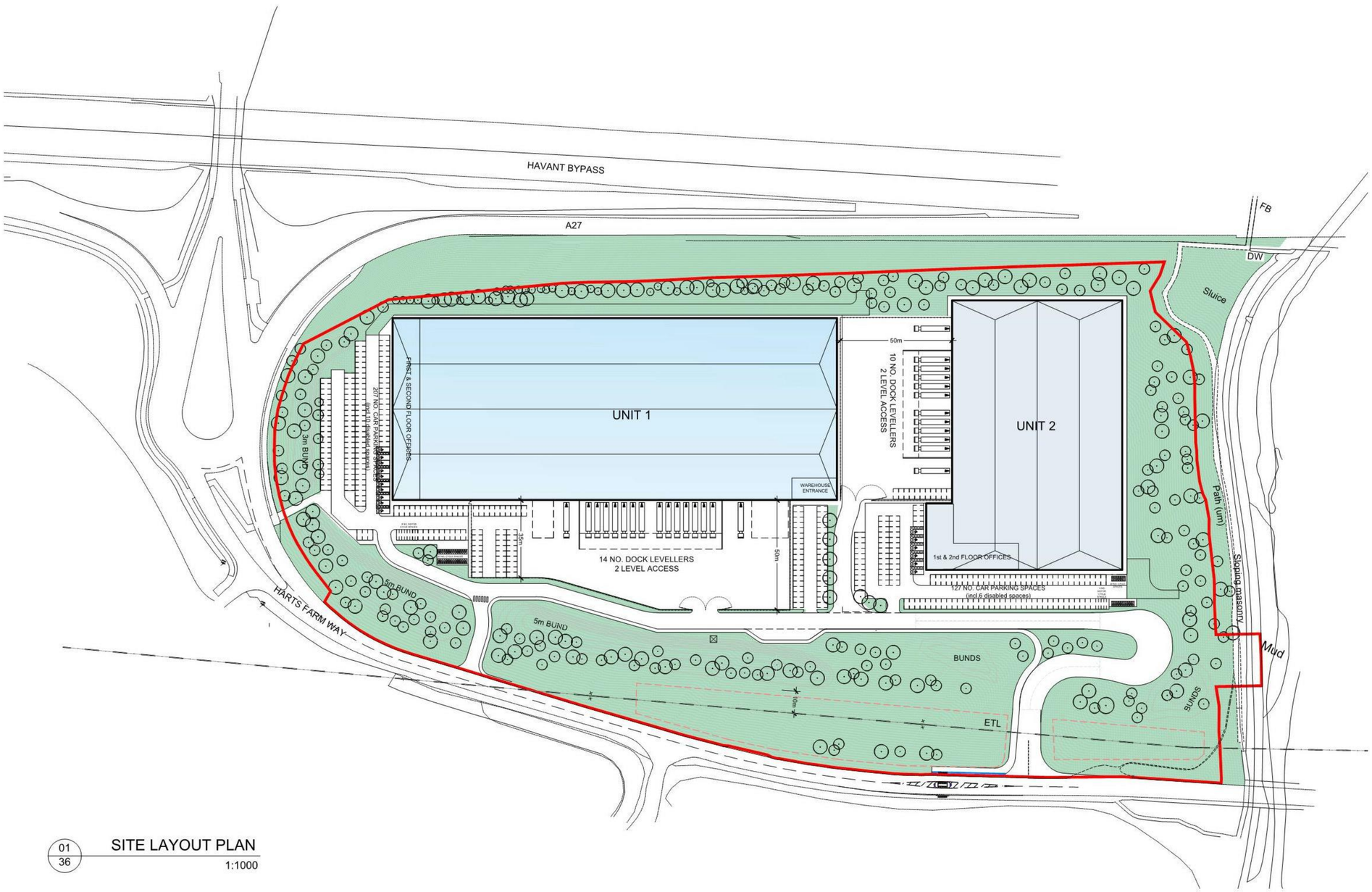
DO NOT SCALE THIS DRAWING

DO NOT USE ELECTRONIC VERSIONS OF THIS DRAWING TO DETERMINE DIMENSIONS UNLESS SPECIFICALLY AUTHORISED BY MICHAEL SPARKS ASSOCIATES

IF USING AN ELECTRONIC VERSION OF THIS DRAWING FIGURED DIMENSIONS TAKE PRECEDENCE AND NOTIFY MICHAEL SPARKS ASSOCIATES OF ANY DISCREPANCIES

N

0 25 50 100m



01
36

SITE LAYOUT PLAN
1:1000

AREA SCHEDULE

GIA

1	sqm	sqft
Unit	16,169	174,045
2 Storey Offices	1,803	19,405
Subtotal	17,972	193,450

2	sqm	sqft
Unit	9,426	101,460
2 Storey Offices	1,296	13,950
Subtotal	10,722	115,410

TOTAL	28,694	308,860

SITE AREA (APPROX.)	Ha	acres
	8.357	20.649

FEASIBILITY

REV	DATE	NOTE	DRAW	CHCK
–	13/05/2021	First Issue	PB	AC

MICHAEL SPARKS ASSOCIATES
CHARTERED ARCHITECTS
11 PLATO PLACE
ST.DIONIS ROAD
LONDON SW6 4TU
TELEPHONE 020 7736 6162
www.msa-architects.co.uk

TITLE
HARTS FARM WAY, HAVANT

DRAWING
SITE LAYOUT PLAN

CLIENT
EXTON ESTATES

DATE	SCALE	DRAWN
MAY 2021	1:1000 @ A1	PB
	STATUS: FEASIBILITY	CHECKED: AC

DRAWING NUMBER
31383 / FE / 37

Drawing 2 – WYG Exploratory Hole Location Plan

DO NOT SCALE: CONTRACTOR TO CHECK ALL DIMENSIONS AND REPORT ANY OMISSIONS OR ERRORS

KEY:

BOREHOLE

WINDOW SAMPLE

WINDOW SAMPLE

N

Track

A27

Playing Field

Broad Marsh

Path

HARTS FARM W

DRAFT

Contains Ordnance Survey data © Crown copyright and database right 2015

0 10 20 30 40 50 m

SCALE 1:1000

REV	DESCRIPTION	BY	CHK	APP	DATE

180 St. John Street
London
EC1V 4BH

TEL: +44 (0)20 7250 7500
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	RP	24.07.17	NB	24.07.17		

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

WYG Group Ltd.

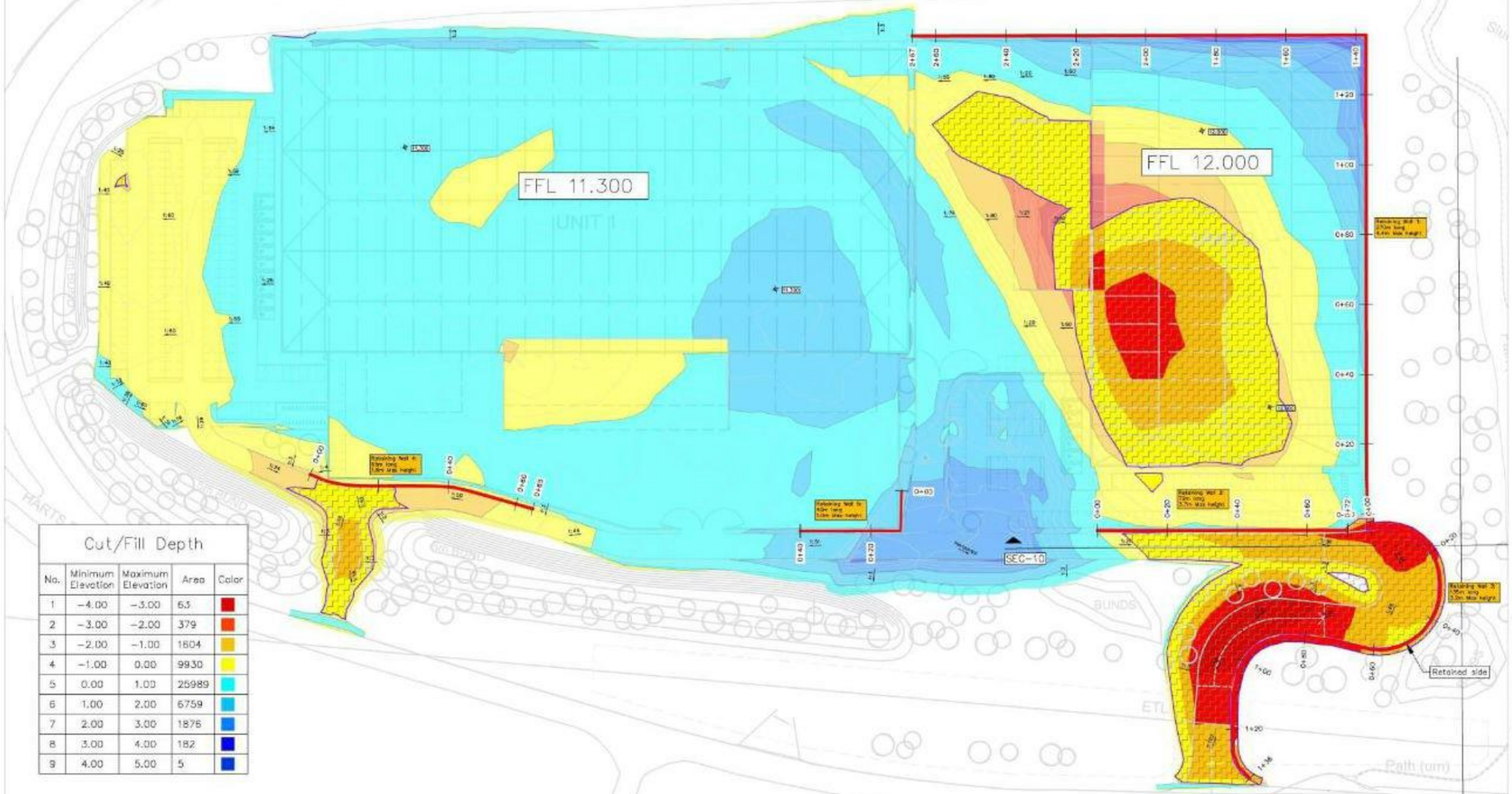
Drawing 3 – Earthworks Analysis by Readie Construction Limited (Ref: RCL-CP143-EW-051)

Construction build-ups

	Area	Finishes	m3	Type1	m3	GF	m3	BBB Capping minimum depth	m3	O/A depth to formation
Car Park & FP's		150	0	300	0	0	0	500	0	950
Landscaping		300	0	0	0	0	0	500	0	800
Road - HGV		250	0	300	0	0	0	500	0	1050
Road - Car Park		150	0	300	0	0	0	500	0	950
Service Yard		200	0	250	0	0	0	500	0	950
Warehouse & Dock Slab		300	0	50	0	400	0	500	0	1250
Totals	0		0		0		0		0	

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
VOL_MISC - Site Strip	1.000	1.000	51584.91sq.m	14522.49 Cu. M.	0.00 Cu. M.	14522.49 Cu. M.<Cut>
Totals			51584.91sq.m	14522.49 Cu. M.	0.00 Cu. M.	14522.49 Cu. M.<Cut>



Cut/Fill Depth

No.	Minimum Elevation	Maximum Elevation	Area	Color
1	-4.00	-3.00	65	
2	-3.00	-2.00	379	
3	-2.00	-1.00	1604	
4	-1.00	0.00	9930	
5	0.00	1.00	25989	
6	1.00	2.00	6759	
7	2.00	3.00	1876	
8	3.00	4.00	182	
9	4.00	5.00	5	

BBB Cut Areas (Hatched):
Topsoil strip depth varies (included in site strip).
Remove overburden: 13413m3
Cut into BBB to allow 0.5m of clean material caping: 10691m3
Fill to achieve formation levels: 4344m3

Remaining site area:
Topsoil strip depth varies (included in site strip).

Cut into existing overburden: 7281m3
Fill to achieve formation levels: 25010m3

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
VOL_PART - BBB Cut Areas - Overburden removal	1.000	1.000	8667.23sq.m	13413.32 Cu. M.	0.00 Cu. M.	13413.32 Cu. M.<Cut>
VOL_PART - BBB Cut Areas - Overburden Fill	1.000	1.000	8688.20sq.m	0.00 Cu. M.	4344.10 Cu. M.	4344.10 Cu. M.<Fill>
Totals			17355.43sq.m	13413.32 Cu. M.	4344.10 Cu. M.	9069.22 Cu. M.<Cut>

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
VOL_MERGE - Site Cut-Fill	1.000	1.000	46787.63sq.m	7281.54 Cu. M.	25010.53 Cu. M.	17728.99 Cu. M.<Fill>
Totals			46787.63sq.m	7281.54 Cu. M.	25010.53 Cu. M.	17728.99 Cu. M.<Fill>

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
VOL_PART - BBB Cut	1.000	1.000	8688.43sq.m	10697.88 Cu. M.	6.94 Cu. M.	10691.94 Cu. M.<Cut>
Totals			8688.43sq.m	10697.88 Cu. M.	6.94 Cu. M.	10691.94 Cu. M.<Cut>

Notes:

1. Design responsibility remains with the project appointed consultants.This indicative drawing is provided for information only.
2. Existing levels surface based on:
   COLLIER - 38147_T_REVO_3D
3. Site layout and proposed evels based on:
   X - Surface Finishes Model 2 Unit
4. Topsoil site strip based on borehole logs records.
5. For retaining wall elevations refer to:
   RCL-CP143-EW-071, 072

TOPSOIL STRIP:

	Volume
Site strip topsoil	14522
Topsoil required for landscaping	-1500
Landscaping bunds	0
Surplus topsoil	13022

OVERBURDEN BALANCE:

	Volume
BBB 'Cut areas' ballance	9069
Site' cut/fill balance	-17729
Totals	**-8660**

BBB CUT MATERIAL:

10691m3 to be removed from site

ARISINGS ESTIMATE (does not include retaining walls):

55000m2 x 0.12m = 6600m3

Revisions

Rev.	Details	Date	By
1	Retaining walls added.	28-04-2021	GB
2	.....	.....	GB

readie

Readie construction Limited
Unit 15, Falcon Business Centre
Ashton Road, Romford
RM3 8UR

Contract Name & No:	CP143 Havant		
Drawing Title:	Earthworks Analysis		
Drawing No:	RCL-CP143-EW-051		
Revision:	1	Scale:	NTS
Drawn by:	GB	Date:	28-04-2021

Drawing 4 – Indicative Landscape Sections, Harts Farm Way, Brockhampton West, Havant by Pegasus Design (Ref: P21-1528_16)

Section A-AA (Scale 1:250)

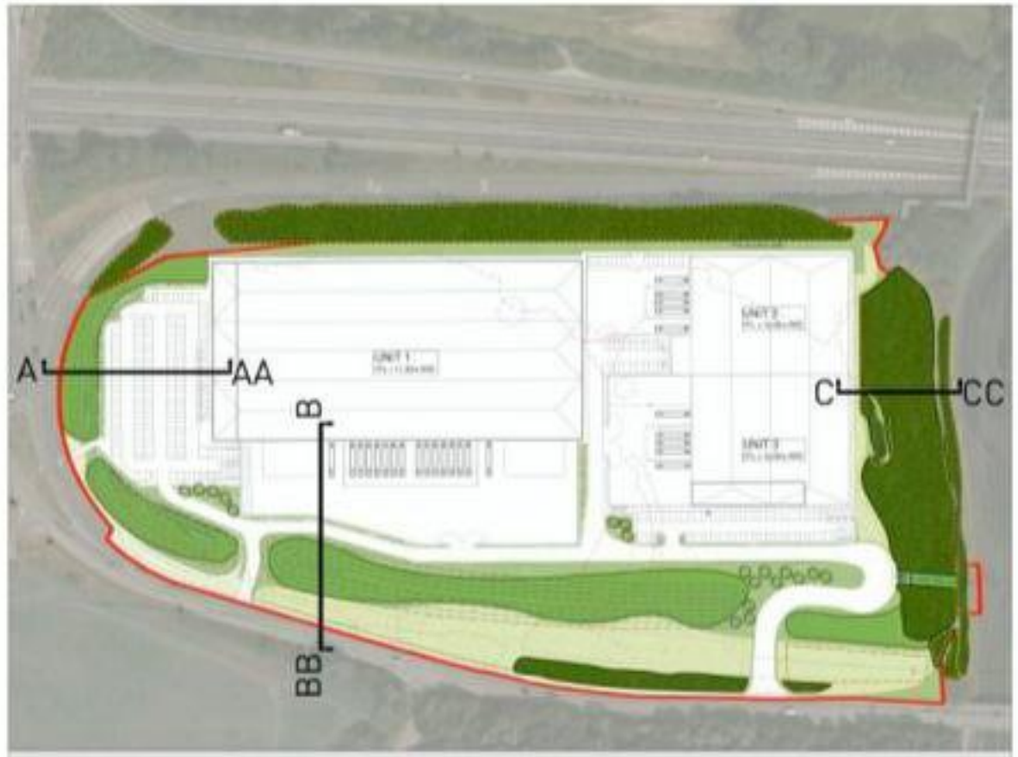


Section B-BB (Scale 1:250)



Section C-CC (Scale 1:250)





Section Location Plan (Scale 1:1500)

Indicative Planting Schedule

Species	Common Name	Specimen/Age	Spacing	Height Year 1	Height Year 5	Height Year 10	Height Year 15	Mature Height
Acer campestre	Field maple	S	50-80cm B/R	0.5	4	6-8	11	15
Acer campestre	Field maple	S	12-14cm B/R	3.0	5.5	8	10.5	15
Acer campestre	Field maple	S	7-10cm Hdr	1.5	4	6-8	9	15
Alnus glutinosa	Alder	S	50-80cm B/R	0.5	4	6-8	11	30
Alnus glutinosa	Alder	S	12-14cm B/R	3.0	5.5	8	10.5	30
Alnus glutinosa	Alder	S	7-10cm Hdr	1.5	4	6-8	9	30
Acer pseudoplatanus	Sycamore	S	12-14cm B/R	3.0	5	7.5	10	30+
Acer pseudoplatanus	Sycamore	M	7-10cm Hdr	1.5	3	4.5	9	30+
Crataegus monogyna	Hawthorn	M	7-10cm Hdr	1.5	3	4	6	8
Corylus avellana	Hazel	M	1.0-1.5m B/G	0.5	3.5	4	4	6
Euonymus europaeus	Spindle	S	80-100cm B/R	0.8	2.5	3.8	6.5	8
Prunus spinosa	Blackthorn	S	80-100cm B/R	0.8	2.5	3.8	6.5	8
Quercus robur	Pedunculate Oak	S	12-14cm B/R	3.0	5.5	8	10.5	30+
Quercus robur	Common Oak	M	7-10cm Hdr	1.5	4	6-8	9	30+
Rosa canina	Dog Rose	S	80-100cm B/R	0.8	2	3	5	7
Salix caprea	Goat Willow	M	80-100cm B/R	0.8	3.5	4.5	6.5	6.5
Viburnum opulus	Guelder Rose	S	80-100cm B/R	0.8	2.5	3.8	6.5	8

Revisions
First Issue - 30/03/2021 JH

Indicative Landscape Sections

Harts Farm Way, Brockhampton West, Havant

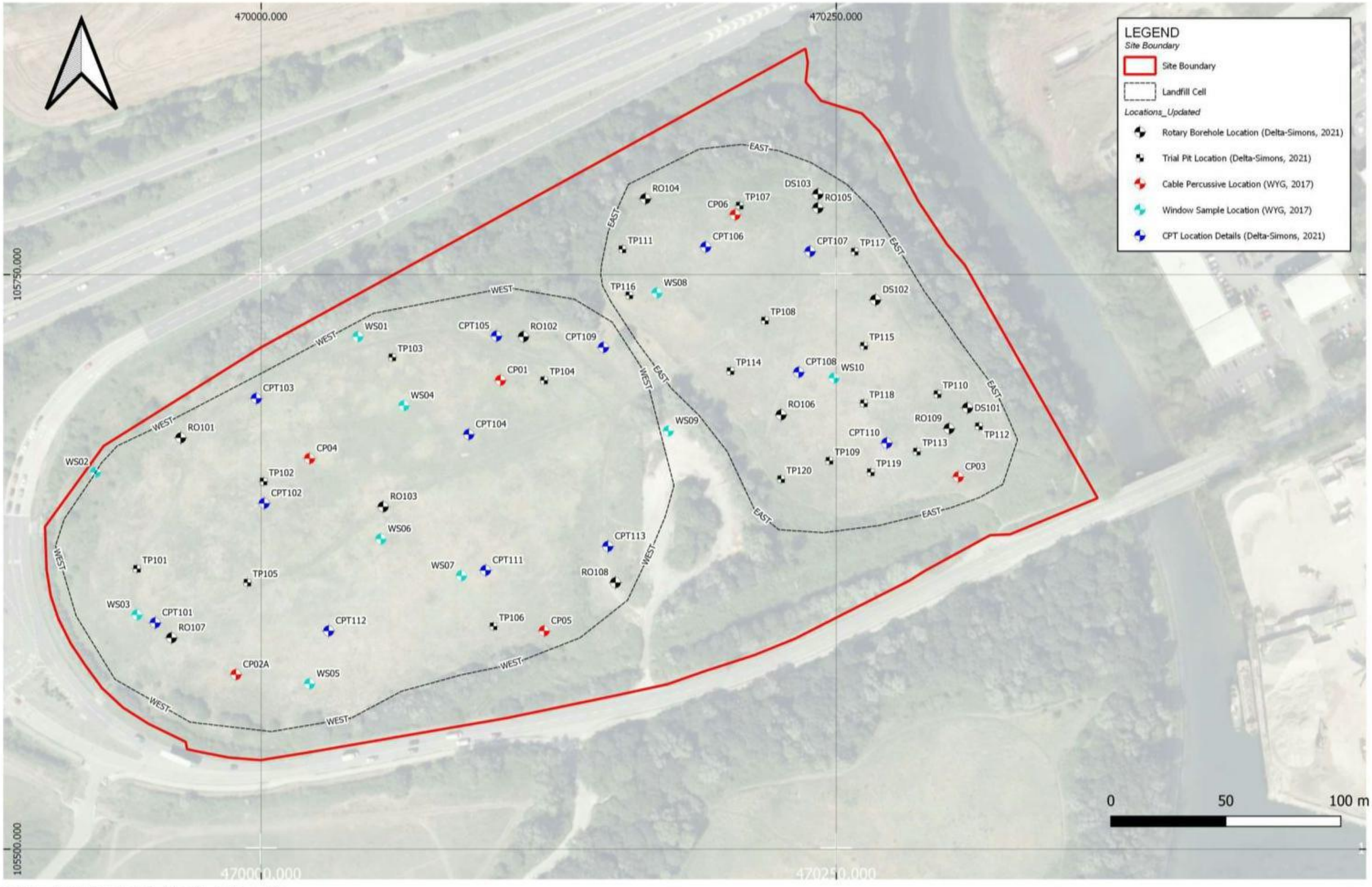
Client: Clowes Developments (UK) Ltd
DRWG No: **P21-1528_16** Sheet No: _ REV: _
Drawn by: JN Approved by: RF
Date: 22/03/2021
Scale: 1:250 @ A1

0 25m

Pegasus Group

Pegasus Planning Group Ltd. © Crown copyright and database rights 2021 Ordnance Survey 100020449. Emapsite Licence number 0100031673. © Getmapping Plc Licence number 100020449. Pegasus accepts no liability for any use of this document other than for the original purpose, or by the original client, in following Pegasus' express agreement to such use. T 01285 641717 www.pegasusgroup.co.uk

Figure 1 – Exploratory Hole Location Plan



Aerial Photography (c) Bing Maps 2021. Data from WYG, 2017 and Delta-Simons 2021.

deltasimons
Environment - Health & Safety - Sustainability

TITLE:
Brockhampton West Landfill
Exploratory Hole Location Plan

DRAWN:	SCALE (@A1):	PROJECT NO:
MS	1:1500	19-2099.04
CHECKED:	VERSION:	FIGURE NO:
LB	2	1
DATE:		
13 July 2021		

Figure 2 – Landfill Waste - Proven Depth to Base Plan

LEGEND

Site Boundary

Site Boundary

Exploratory Hole Locations

Rotary/Cable Percussive

Elevation of Landfill Base (proven - m AOD)

- 3.25
- 2.73
- 2.11
- 1.44
- 0.76
- 0.09
- -0.59
- -1.26
- -1.94

Made Ground 0.50 m contours

RO104
CP06
DS103
RO105
DS102
RO102
CP01
RO106
DS101
RO109
CP03
RO101
CP04
RO103
RO108
CP05
RO107
CP02

N

0 20 40 60 80 100 m

PRELIMINARY : FOR DISCUSSION O NOT TO BE USED

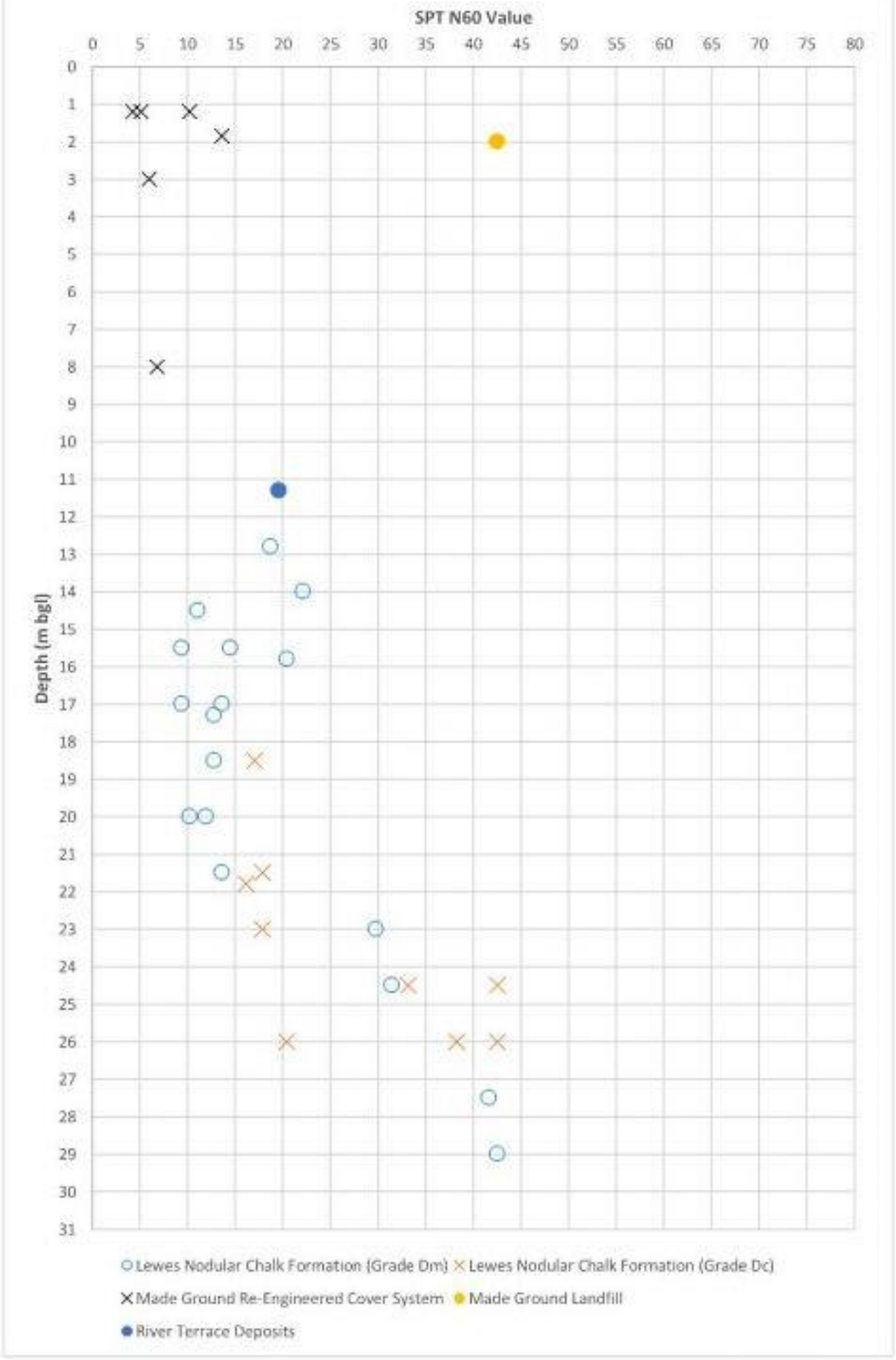
Site Plan Provided by Client.

deltasimons
Environment - Health & Safety - Sustainability

TITLE:
Brockhampton West Landfill
Landfill Interpolated Depth Map

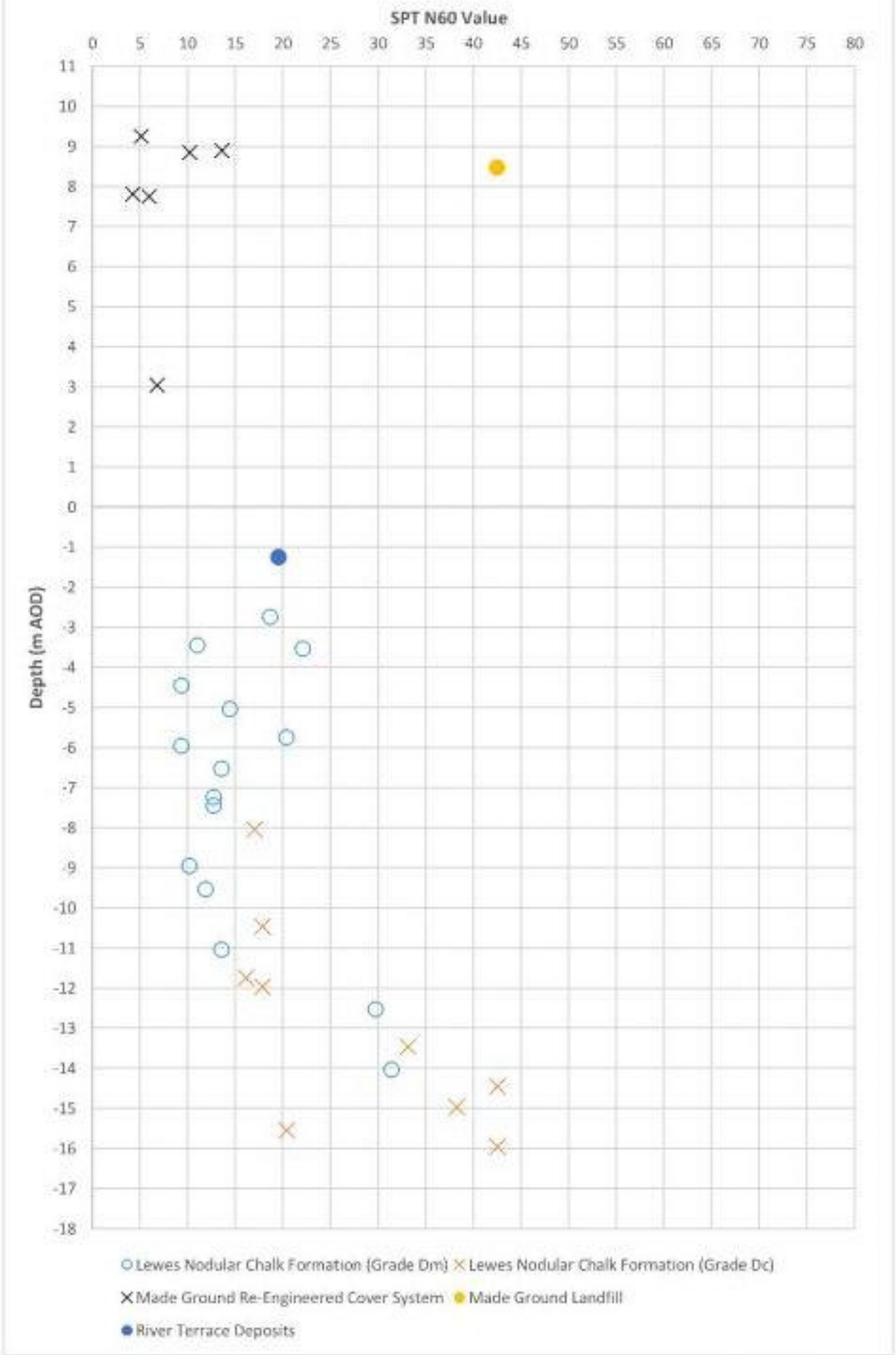
DRAWN BY:	SCALE (@A4):	PROJECT NO:
MS	1:2000	19-2099.04
CHECKED BY:	REVISION:	FIGURE NO:
LB	1	2
DATE:		
21 June 2021		

Figure 3a – SPT vs Depth Plot (m bgl) – West Cell



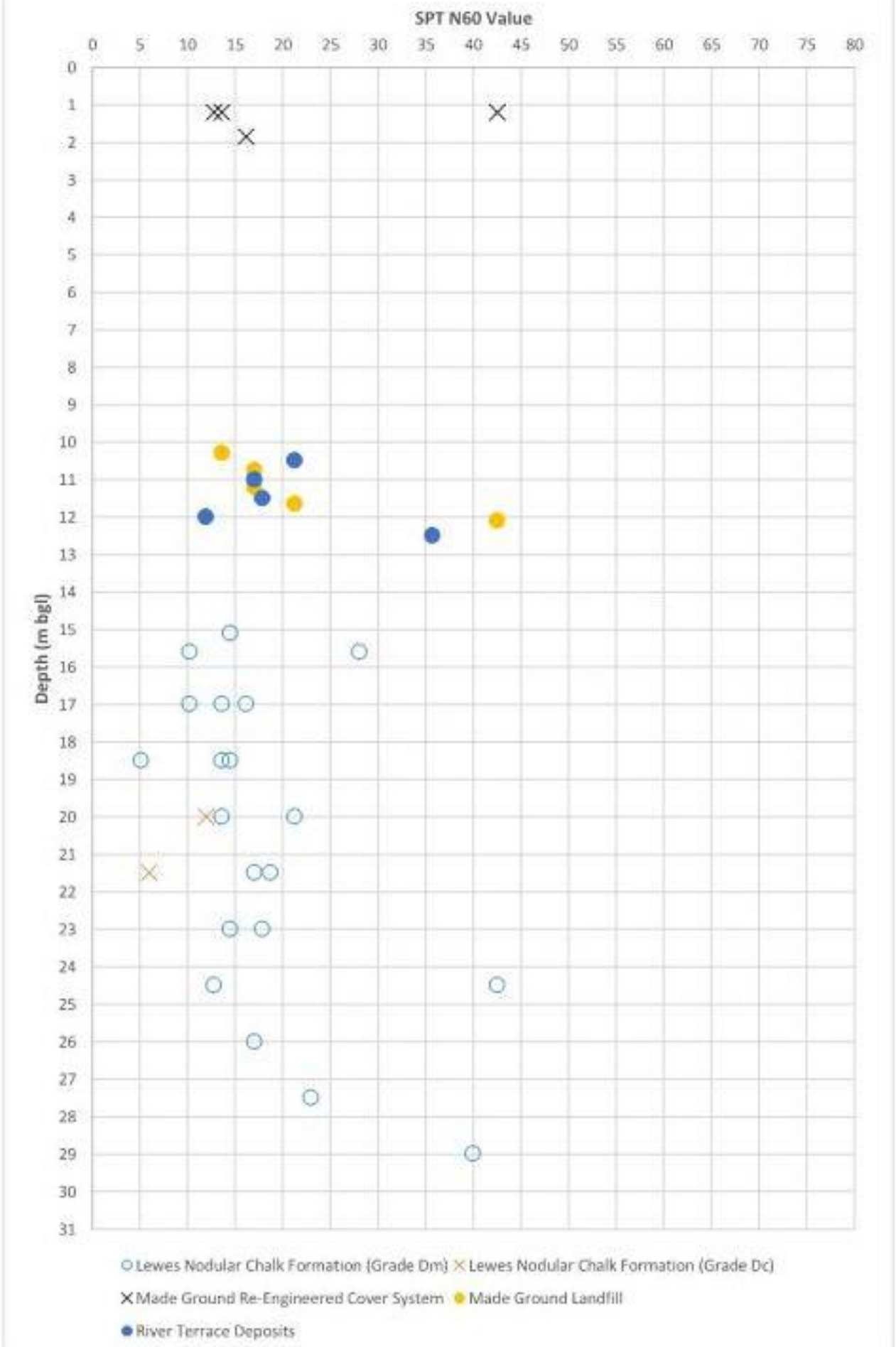
deltasimons	TITLE: Corrected SPT N_{60} Values vs Depth Plot (m bgl) Western Landfill Cell, Brockhampton	DWN: BB	PROJECT NO.: 19-2099.04
		DATE: Jun-21	Figure: 3a

Figure 3b – SPT vs Depth Plot (m AOD) – West Cell



deltasimons	TITLE: Corrected SPT N_{60} Values vs Depth Plot (m AOD) Western Landfill Cell, Brockhampton	DWN: BB	PROJECT NO: 19-2099.04
		DATE: Jun-21	Figure: 3b

Figure 4a – SPT vs Depth Plot (m bgl) – East Cell



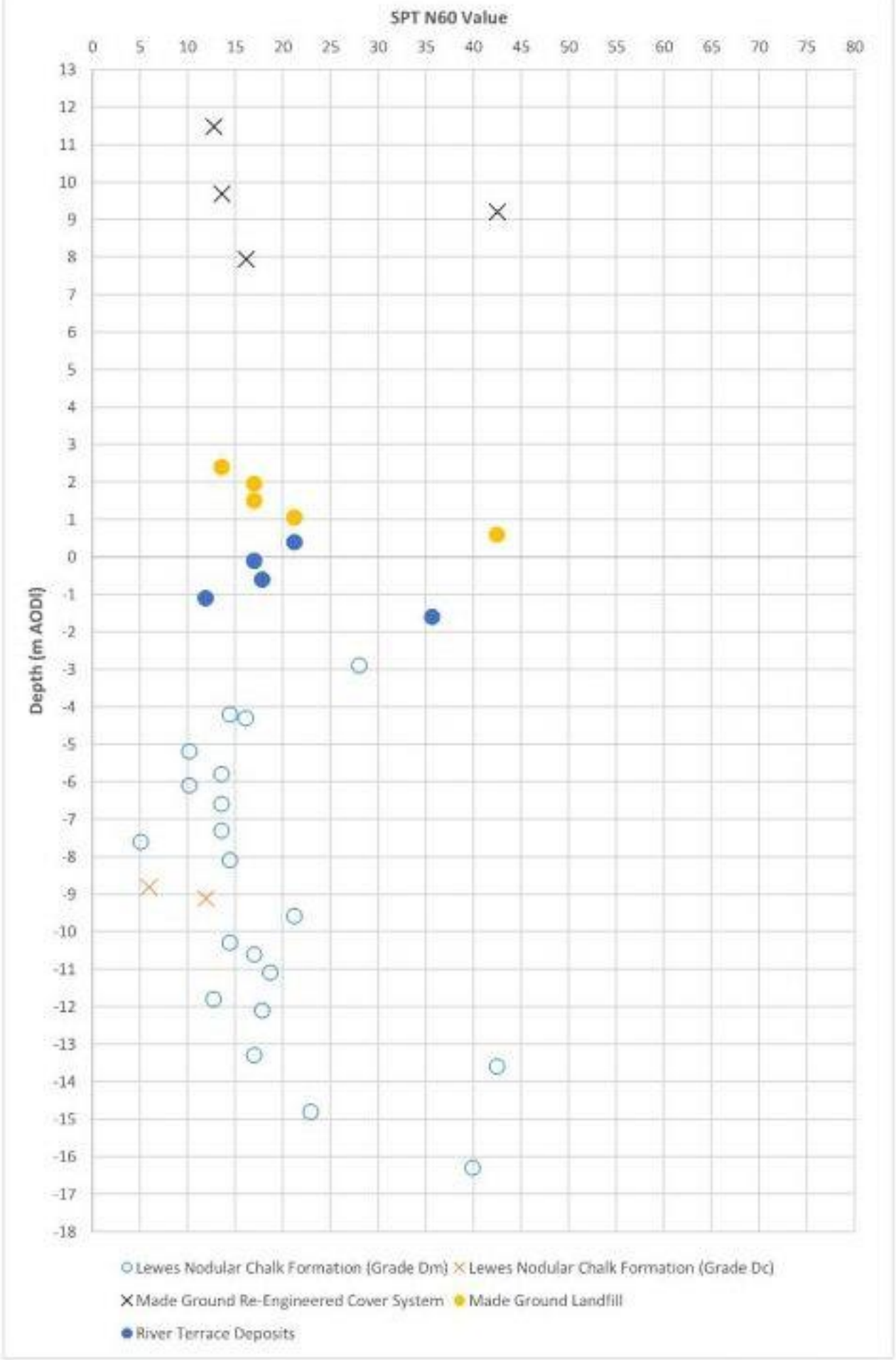
deltasimons

TITLE:

Corrected SPT N_{60} Values vs Depth Plot (m bgl)
Eastern Landfill Cell, Brockhampton

DWN:	PROJECT NO:
BB	19-2099.04
DATE:	Figure:
Jun-21	4a

Figure 4b – SPT vs Depth Plot (m AOD) – East Cell



deltasimons

TITLE:

Corrected SPT N_{60} Values vs Depth Plot
(m AOD)
Eastern Landfill Cell, Brockhampton

DWN:	PROJECT NO:
BB	19-2099.04
DATE:	Figure:
Jun-21	4b

Figure 5 – Granular Re-Engineered Cover System Material Location Plan



Ring. LIDAR Data (C) Environment Agency

deltasimons
Environment - Health & Safety - Sustainability

TITLE:

Granular Re-Engineered Cover System Material Location Plan
Brockhampton West, Havant

DRAWN BY:	SCALE:	PROJECT NO.:
LB	NTS	19-2099.04
CHECKED BY:	REVISION:	FIGURE NO.:
DJ	01	5
DATE:		
25th June 2021		

Figure 6 – Groundwater Contour Plan (Round 4 Groundwater Monitoring)

LEGEND

Site Boundary

Site Boundary

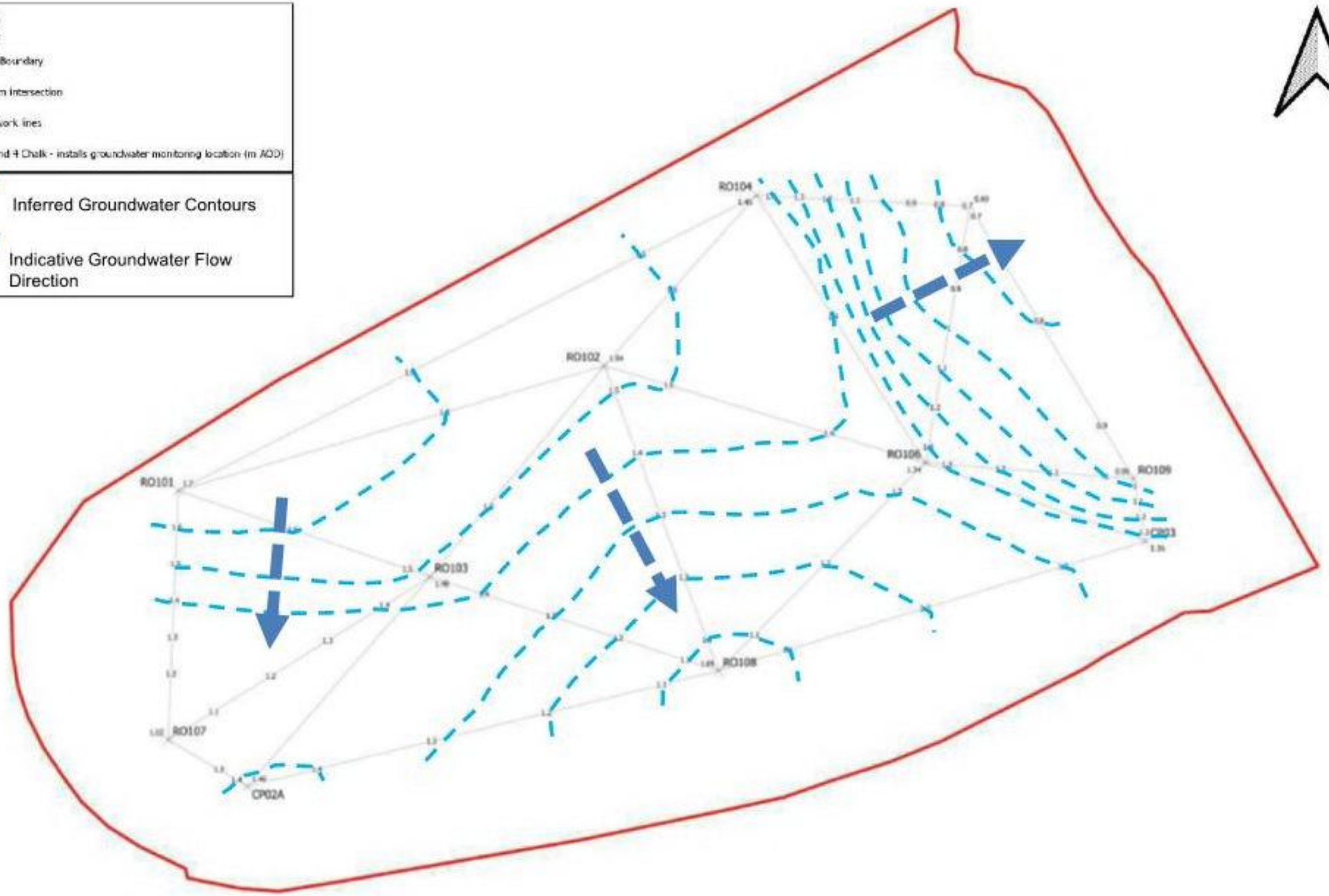
0.1 m Intersection

Network lines

Round 4 Chalk - installs groundwater monitoring location (m AOD)

Inferred Groundwater Contours

Indicative Groundwater Flow Direction



deltasimons Environment - Health & Safety - Sustainability	TITLE: Groundwater Contour Plan (Round 4 Groundwater Monitoring) Brockhampton West, Havant	DRAWN BY: LB	SCALE: NTS	PROJECT NO.: 19-2099.04
		CHECKED BY: DJ	REVISION: 01	FIGURE NO.: 6
		DATE: 29th June 2021		

Appendix A – Limitations

Limitations

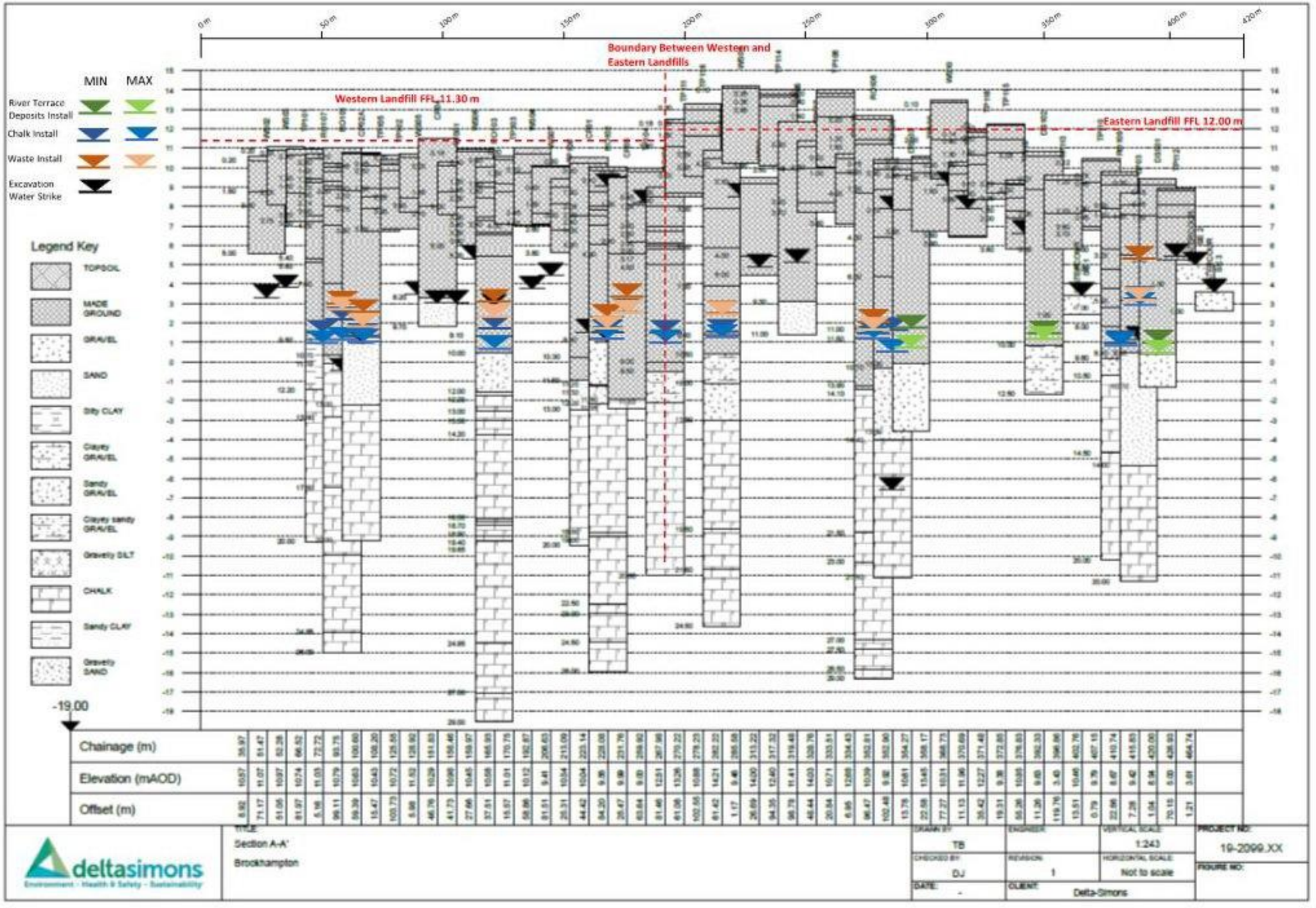
The recommendations contained in this Report represent Delta-Simons professional opinions, based upon the information listed in the Report, exercising the duty of care required of an experienced Environmental Consultant. Delta-Simons does not warrant or guarantee that the Site is free of hazardous or potentially hazardous materials or conditions.

Due to the evolving regulatory climate specific to Per Fluoro Alkyl Substances (PFAS), the scope of works is not intended to be conclusive as it relates to the identification of any PFAS related issues. While Delta-Simons may advise its Client if Delta-Simons becomes aware of the use of PFAS at the subject property, Delta-Simons makes no representation nor accepts any liability that any or all PFAS issues have been identified and/or revealed to its client through its scope of work, as presented herein.

Delta-Simons obtained, reviewed and evaluated information in preparing this Report from the Client and others. Delta-Simons conclusions, opinions and recommendations has been determined using this information. Delta-Simons does not warrant the accuracy of the information provided to it and will not be responsible for any opinions which Delta-Simons has expressed, or conclusions which it has reached in reliance upon information which is subsequently proven to be inaccurate.

This Report was prepared by Delta-Simons for the sole and exclusive use of the Client and for the specific purpose for which Delta-Simons was instructed. Nothing contained in this Report shall be construed to give any rights or benefits to anyone other than the Client and Delta-Simons, and all duties and responsibilities undertaken are for the sole and exclusive benefit of the Client and not for the benefit of any other party. In particular, Delta-Simons does not intend, without its written consent, for this Report to be disseminated to anyone other than the Client or to be used or relied upon by anyone other than the Client. Use of the Report by any other person is unauthorised and such use is at the sole risk of the user. Anyone using or relying upon this Report, other than the Client, agrees by virtue of its use to indemnify and hold harmless Delta-Simons from and against all claims, losses and damages (of whatsoever nature and howsoever or whensoever arising), arising out of or resulting from the performance of the work by the Consultant.

Appendix B – Geological Cross Section

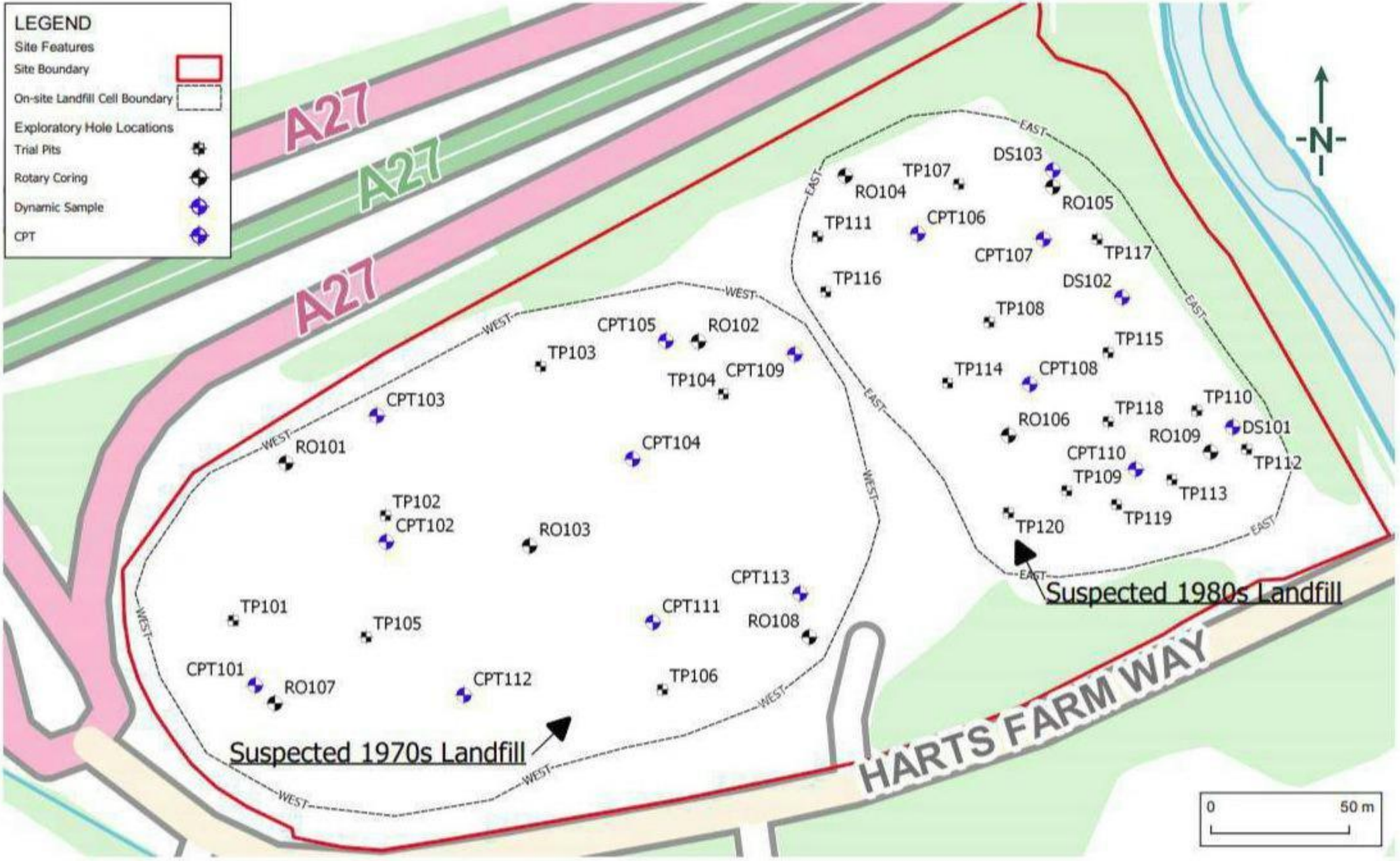


deltasimons
Environment · Health & Safety · Sustainability

TITLE
Section A-A'
Brookhampton

DRAWN BY: TB	ENGINEER:	VERTICAL SCALE: 1:243	PROJECT NO: 19-2099.XX
CHECKED BY: DJ	REVISION: 1	HORIZONTAL SCALE: Not to scale	FIGURE NO:
DATE: -	CLIENT: Delta-Simons		

Appendix C – CPT Data Interpretation


LEGEND
Site Features
Site Boundary
On-site Landfill Cell Boundary
Exploratory Hole Locations
Trial Pits
Rotary Coring
Dynamic Sample
CPT
A27
A27
A27
-N-
EAST
WEST
DS103
TP107
RO104
RO105
TP111
CPT106
CPT107
TP117
TP116
DS102
TP108
TP115
TP114
CPT108
TP110
TP118
RO106
RO109
DS101
CPT110
TP112
TP109
TP113
TP119
TP120
CPT105
RO102
TP103
CPT109
TP104
CPT103
RO101
CPT104
TP102
CPT102
RO103
CPT113
TP101
CPT111
RO108
TP105
CPT101
RO107
CPT112
TP106
Suspected 1980s Landfill
Suspected 1970s Landfill
HARTS FARM WAY
0
50 m

Typical Young's modulus (E') for cohesive and granular material (MPa) (based on Obrzud & Truty 2012 compiled from Kezdi 1974 and Prat et al. 1995)

Description	Very soft to soft	Medium	Stiff to very stiff	Hard
Silts with slight plasticity	2.5 - 8	10 - 15	15 -40	40 - 80
Silts with low plasticity	1.5 - 6	6 -10	10 - 30	30 -60
Clays with low-medium plasticity	0.5 - 5	5 -8	8 - 30	30 - 70
Clays with high plasticity	0.35 - 4	4 -7	7 - 20	20 - 32
Organic silts	-	0.5 -5	-	-
Organic clays	-	0.5 -4	-	-

Description	Loose	Medium	Dense
Gravels/Sand well-graded	30-80	80-160	160-320
Sand, uniform	10-30	30-50	50-80
Sand/Gravel silty	7-12	12-20	20-30

Deriving E’ from Coefficient of Volume Change Potential (m_v)

$$1/m_v = E'$$

IN SITU
SITE INVESTIGATION Working with: deltasimons

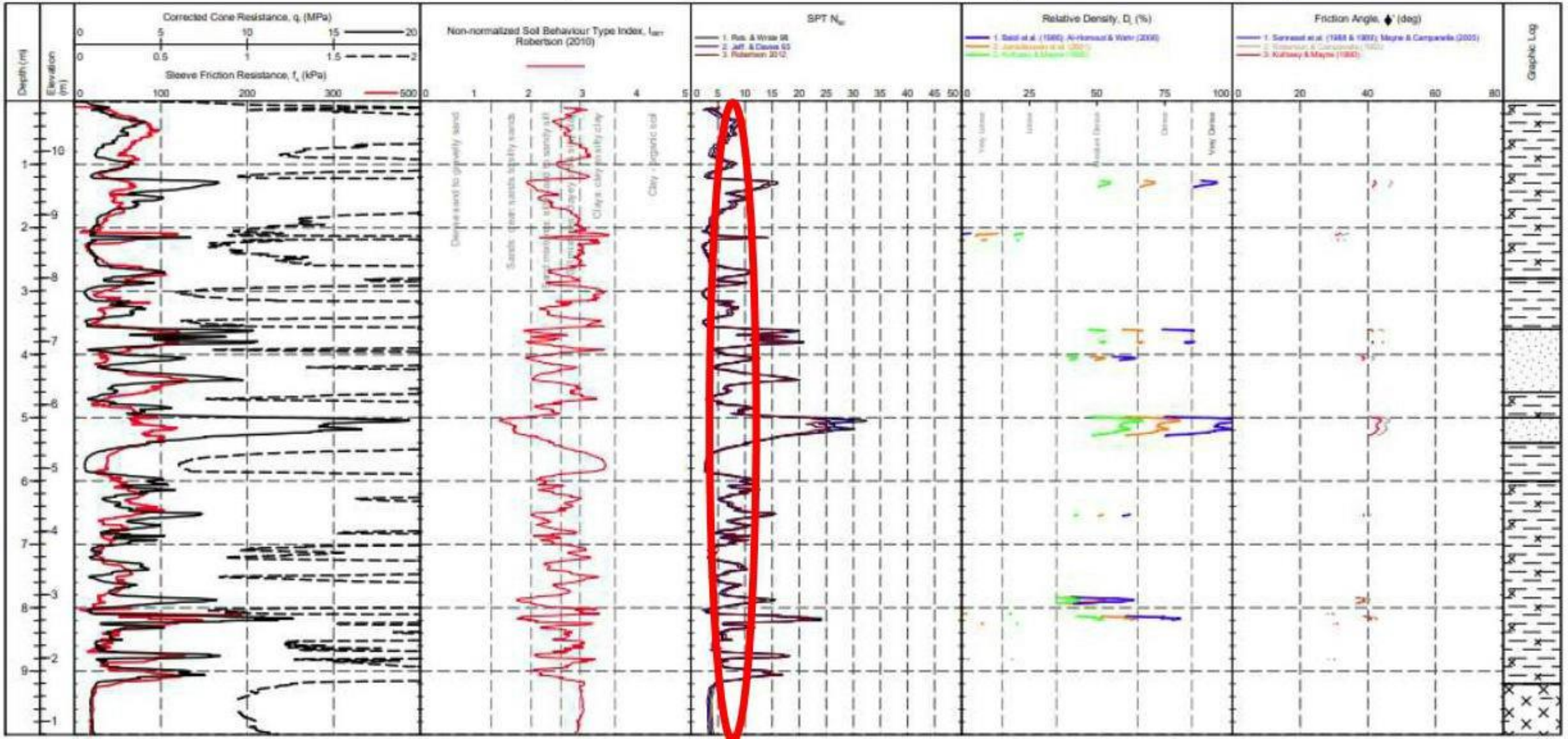
PointID
CPT101

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Brockhampton
PROJECT No. : 1210220

EASTING : 469953.9 m
NORTHING : 105598.5 m
ELEVATION : 10.79 m OD
CHECKED BY : LD
TERMINATION REASON : Refusal

Remark:
Test refused on total pressure.

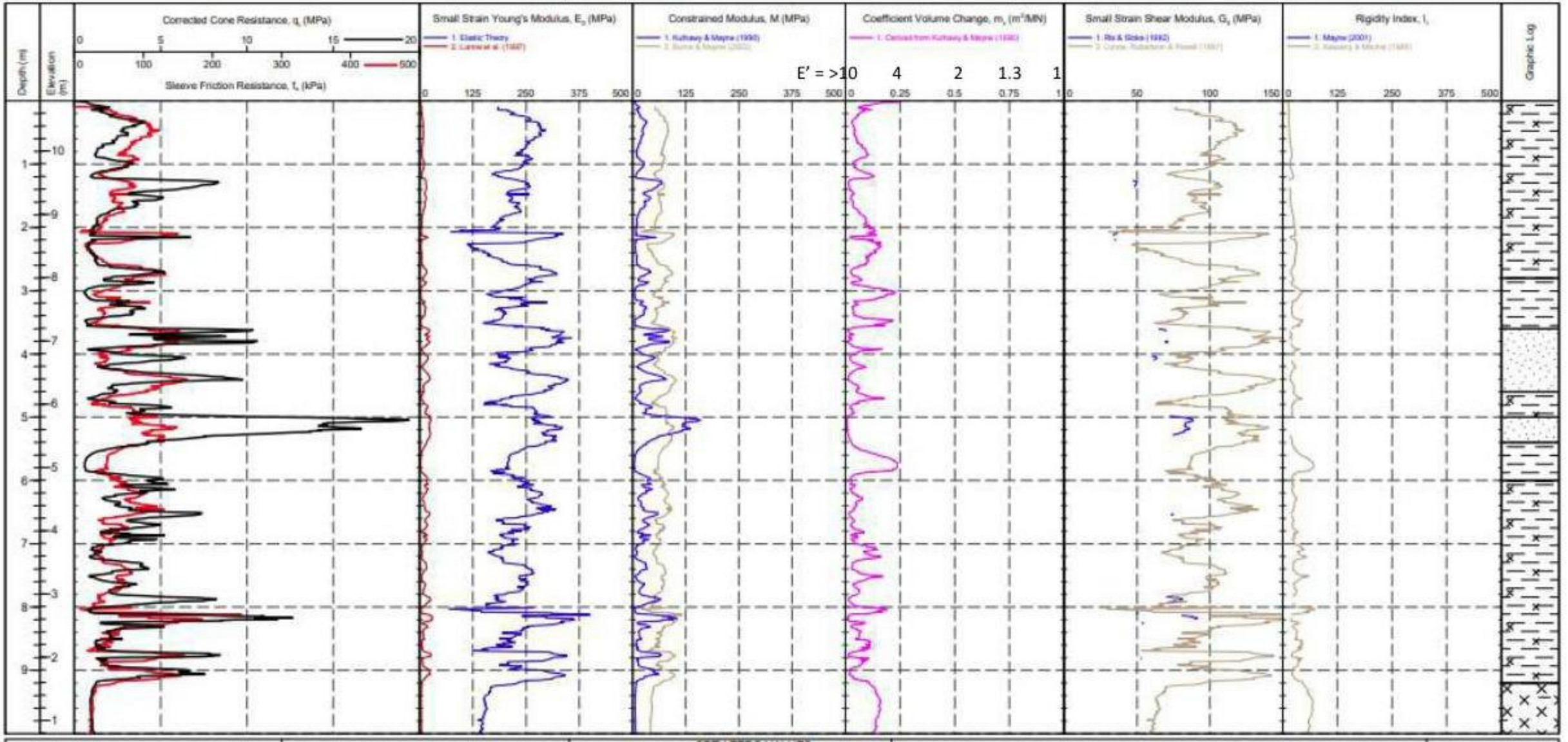
SHEET : 1 OF 4
STATUS : Final
TEST DATE : 29/03/2021
PLOT DATE : 25/05/2021
METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT101

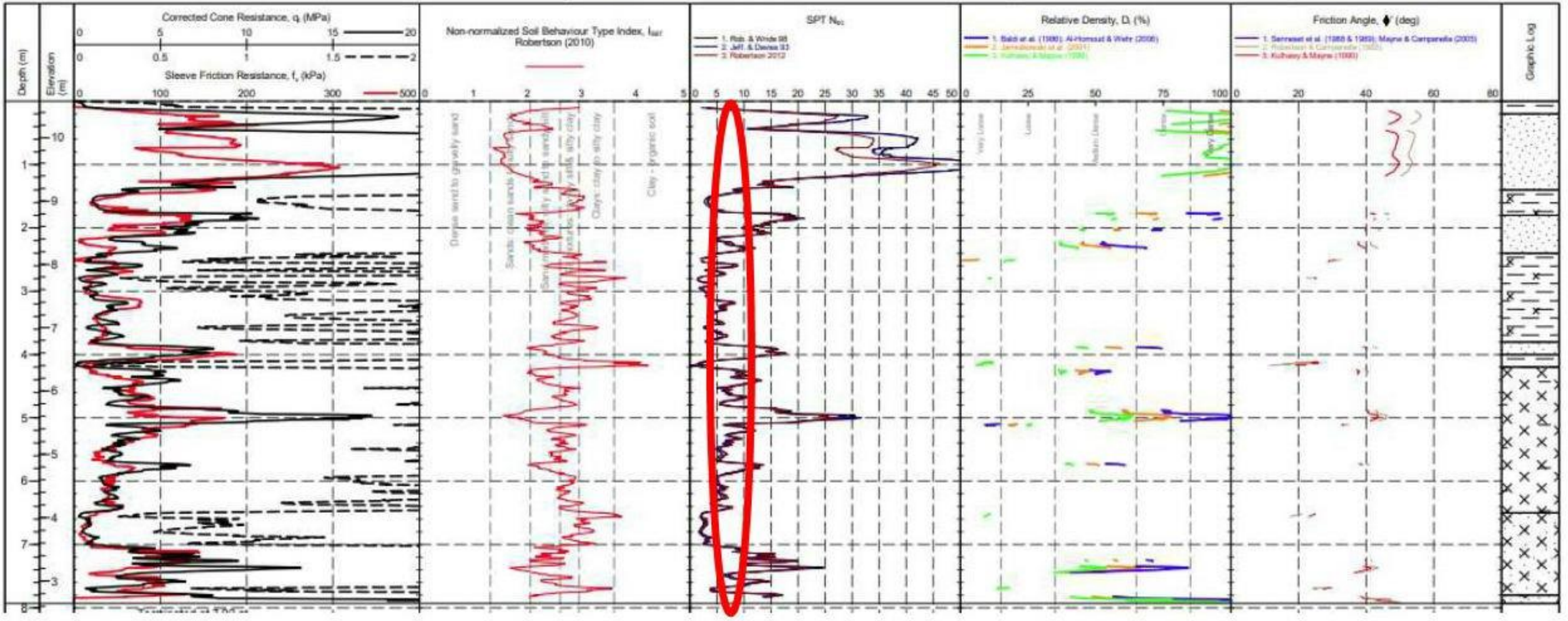
CLIENT : Delta Simons	EASTING : 469953.9 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105598.5 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.79 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT103

CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 469997.8 m NORTHING : 105696.1 m ELEVATION : 10.58 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 1 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with: deltasimons

Lincoln | Durham | Norwich | Leeds | Manchester | London

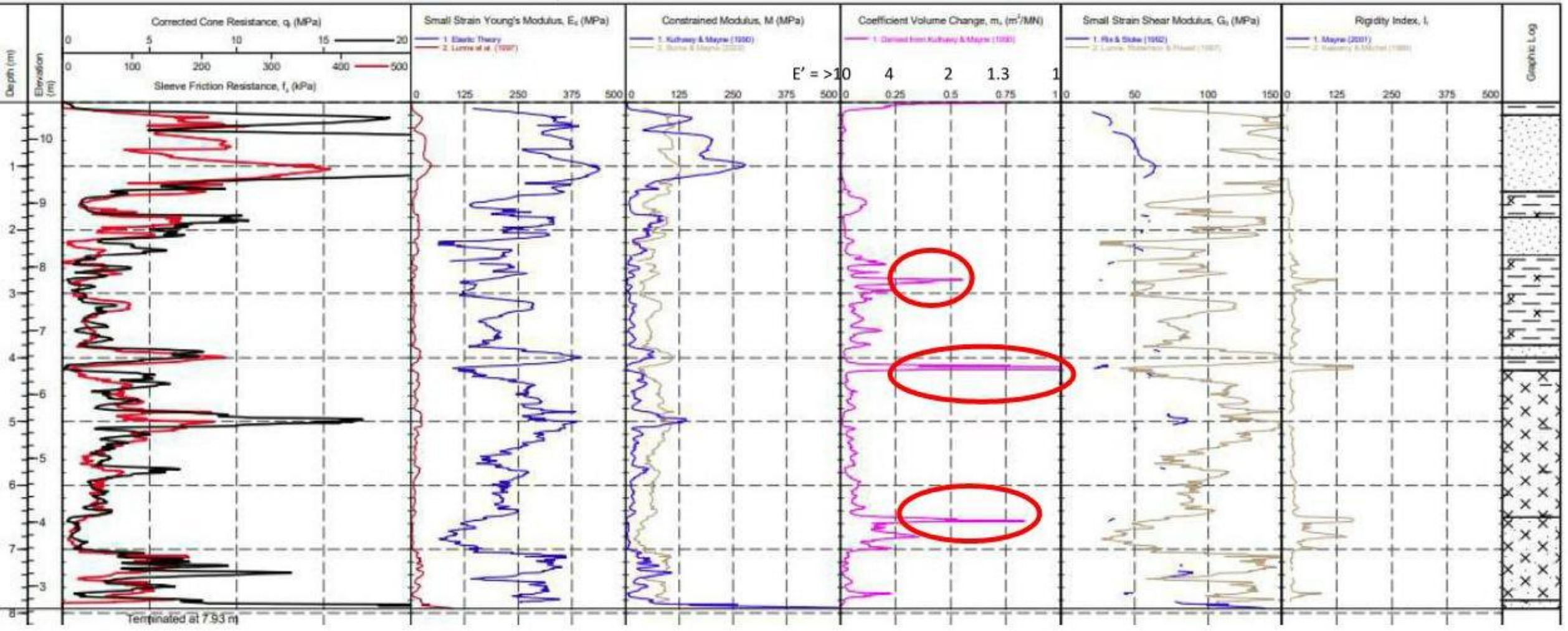
PointID **CPT103**

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Brockhampton
PROJECT No. : 1210220

EASTING : 469997.8 m
NORTHING : 105696.1 m
ELEVATION : 10.58 m OD
CHECKED BY : LD
TERMINATION REASON : Refusal

Remark:
Test refused on total pressure.

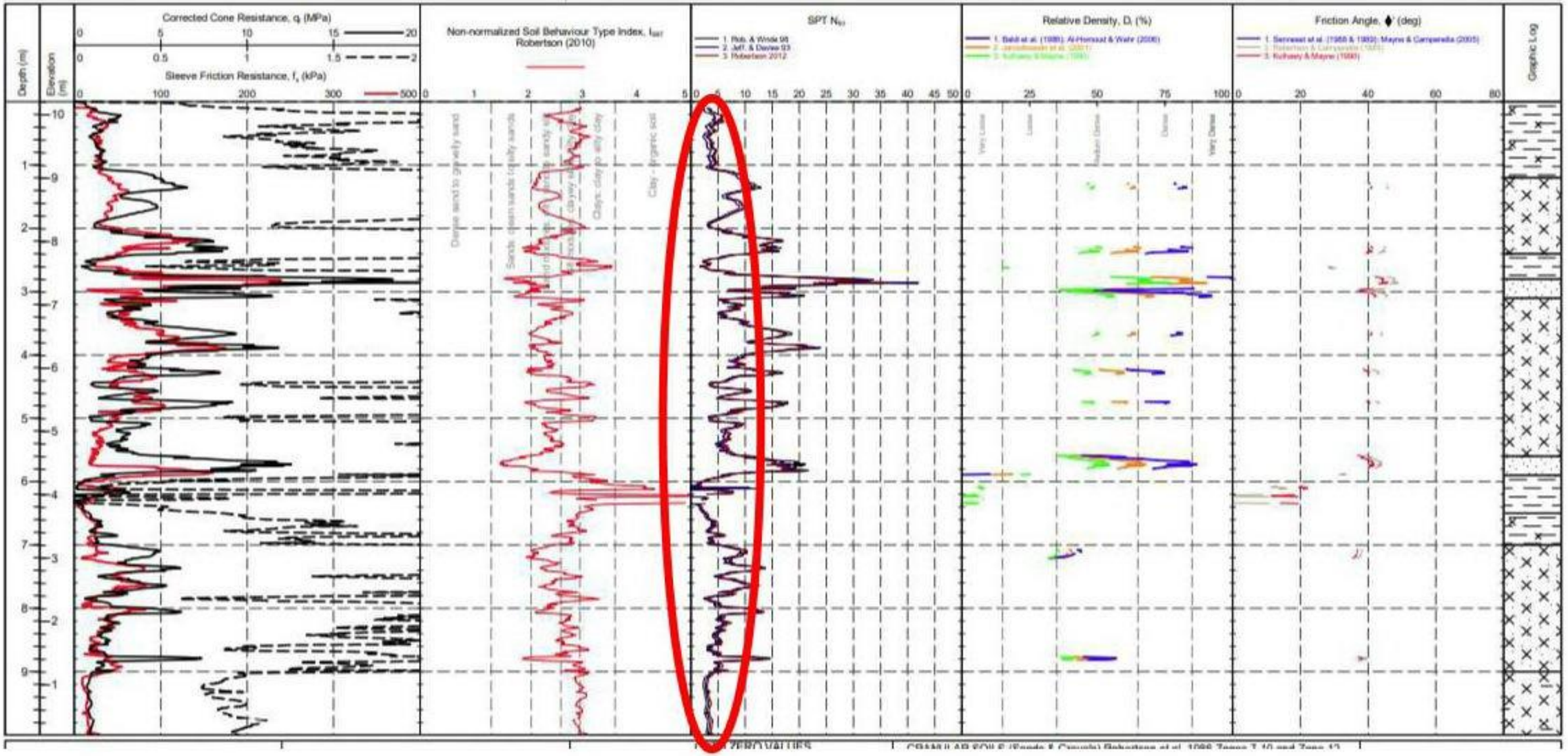
SHEET : 1 OF 1
STATUS : Final
TEST DATE : 29/03/2021
PLOT DATE : 25/05/2021
METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT104

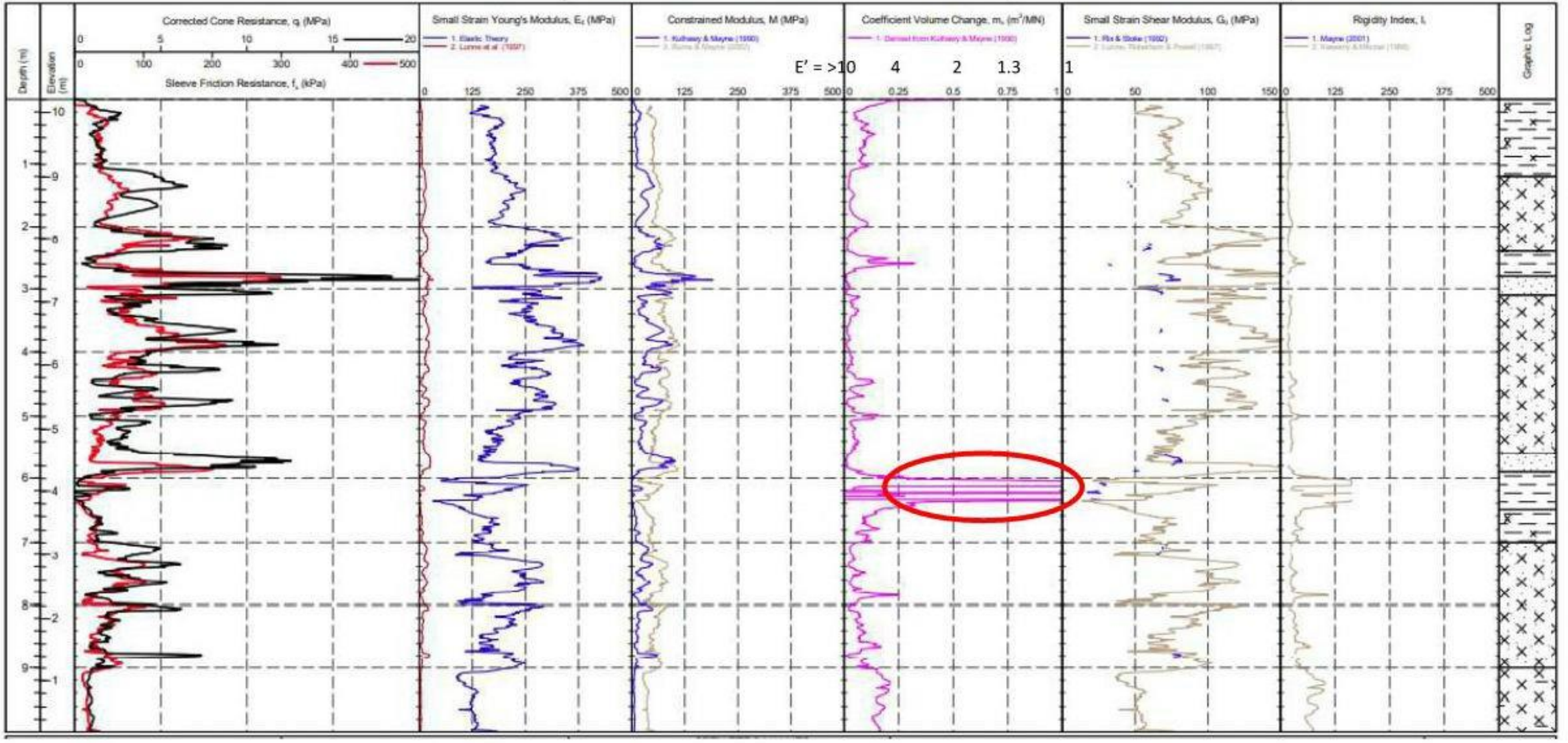
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470090.2 m NORTHING : 105680.5 m ELEVATION : 10.21 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with deltasimons

PointID: **CPT104**

CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470090.2 m NORTHING : 105680.5 m ELEVATION : 10.21 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012

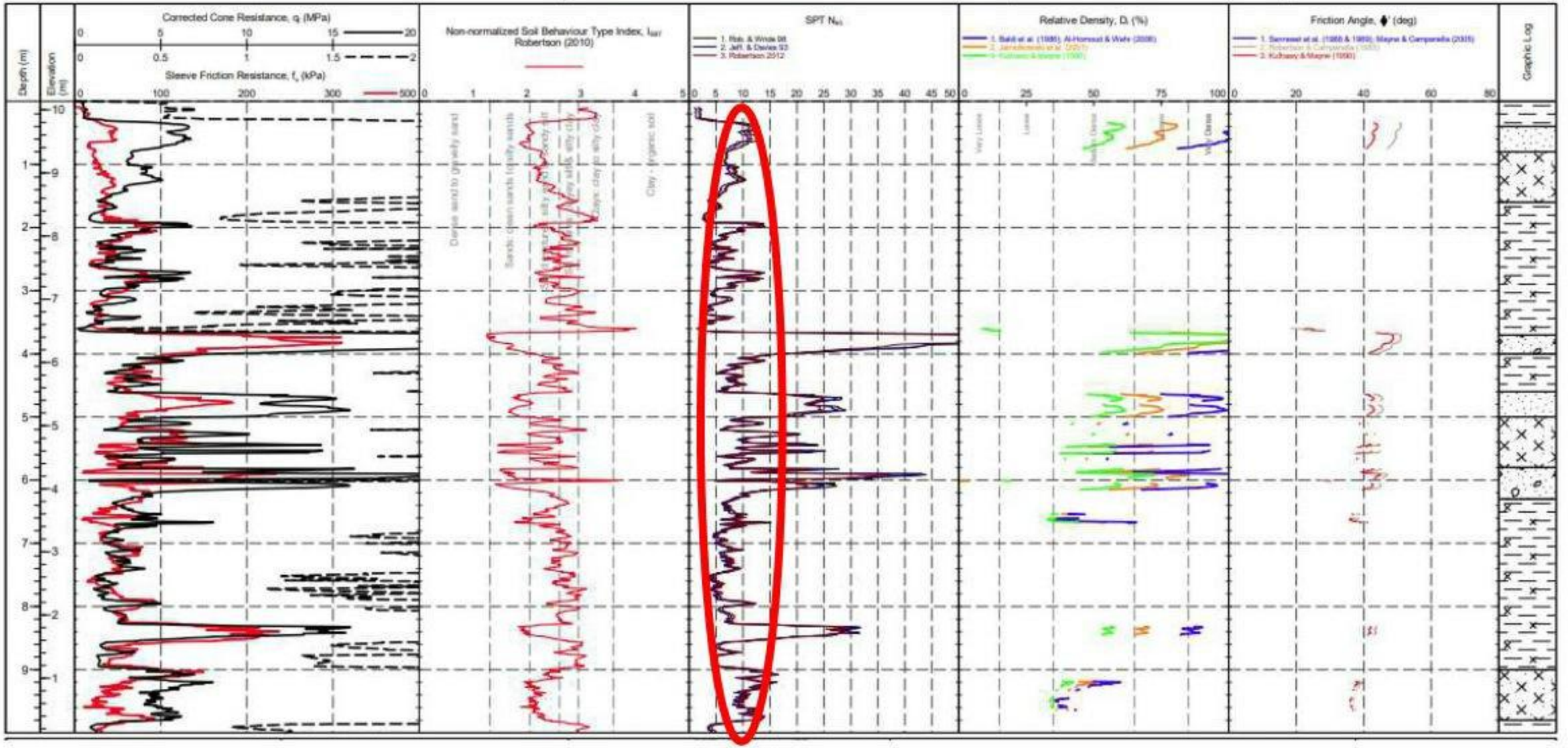


IN SITU
SITE INVESTIGATION Working with: deltasimons

CPT LOG 02

PointID
CPT105

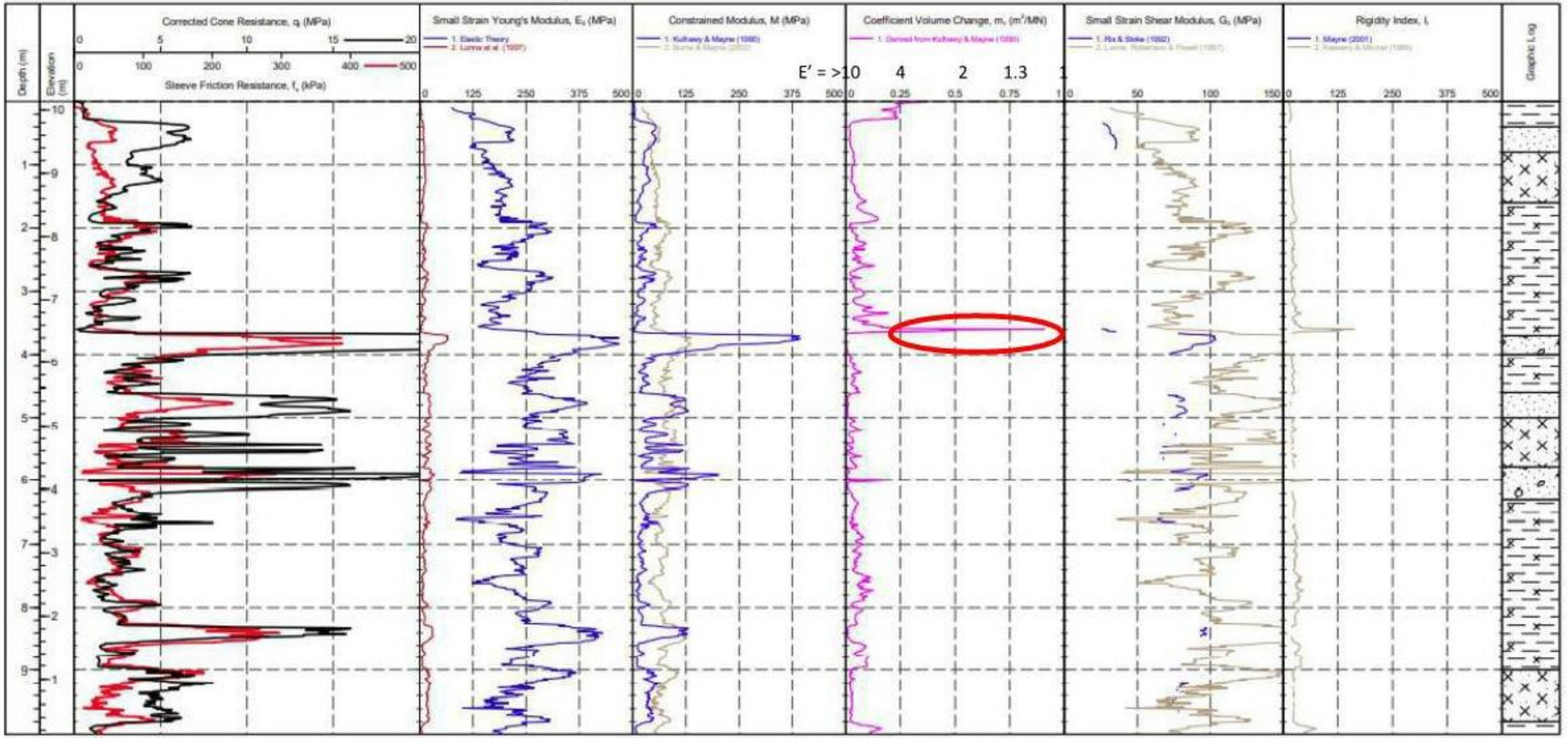
CLIENT : Delta Simons	EASTING : 470102.2 m	Remark:	SHEET : 1 OF 3
PROJECT : Brockhampton	NORTHING : 105723.2 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.14 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU SITE INVESTIGATION Working with: deltasimons

PointID: **CPT105**

CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470102.2 m NORTHING : 105723.2 m ELEVATION : 10.14 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

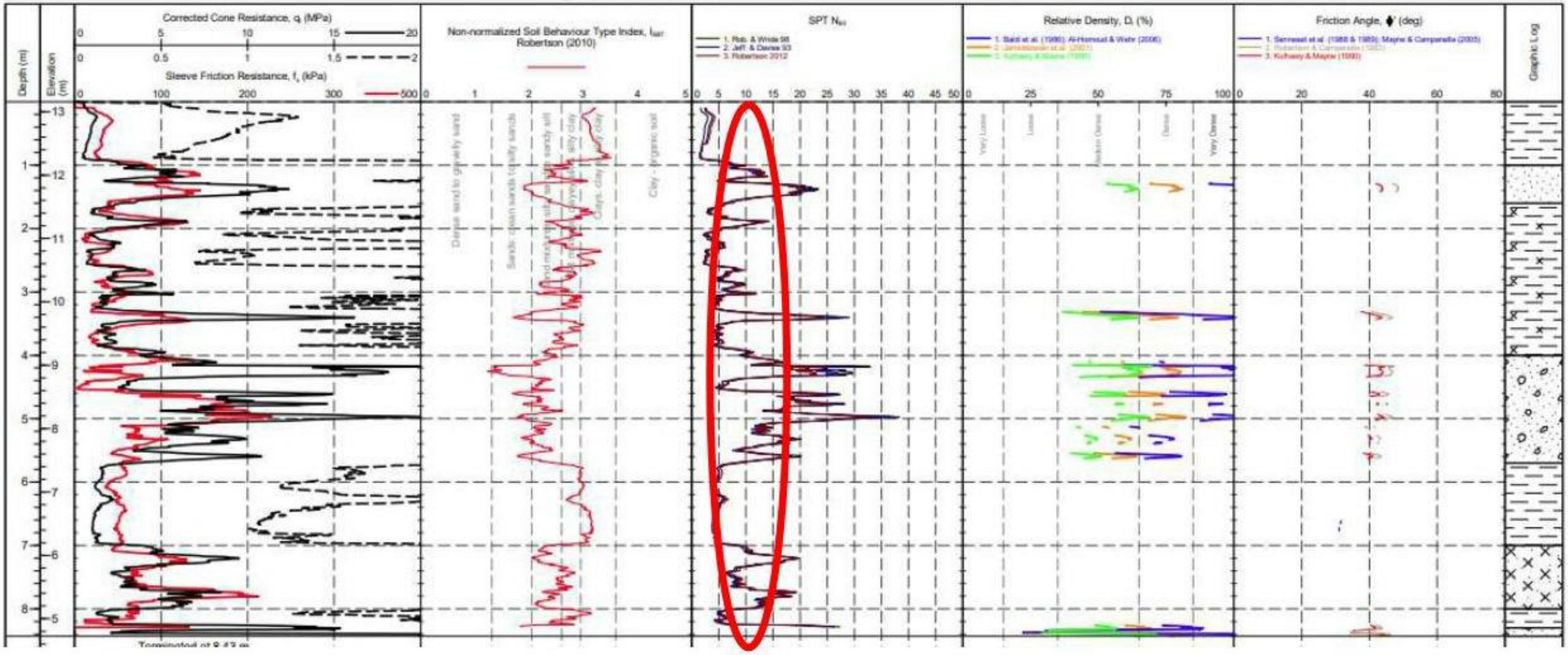
PointID
CPT106

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Brockhampton
PROJECT No. : 1210220

EASTING : 470193.2 m
NORTHING : 105762.0 m
ELEVATION : 13.16 m OD
CHECKED BY : LD
TERMINATION REASON : Refusal

Remark:
Test refused on total pressure.

SHEET : 1 OF 1
STATUS : Final
TEST DATE : 30/03/2021
PLOT DATE : 25/05/2021
METHOD : ISO 22476-1:2012



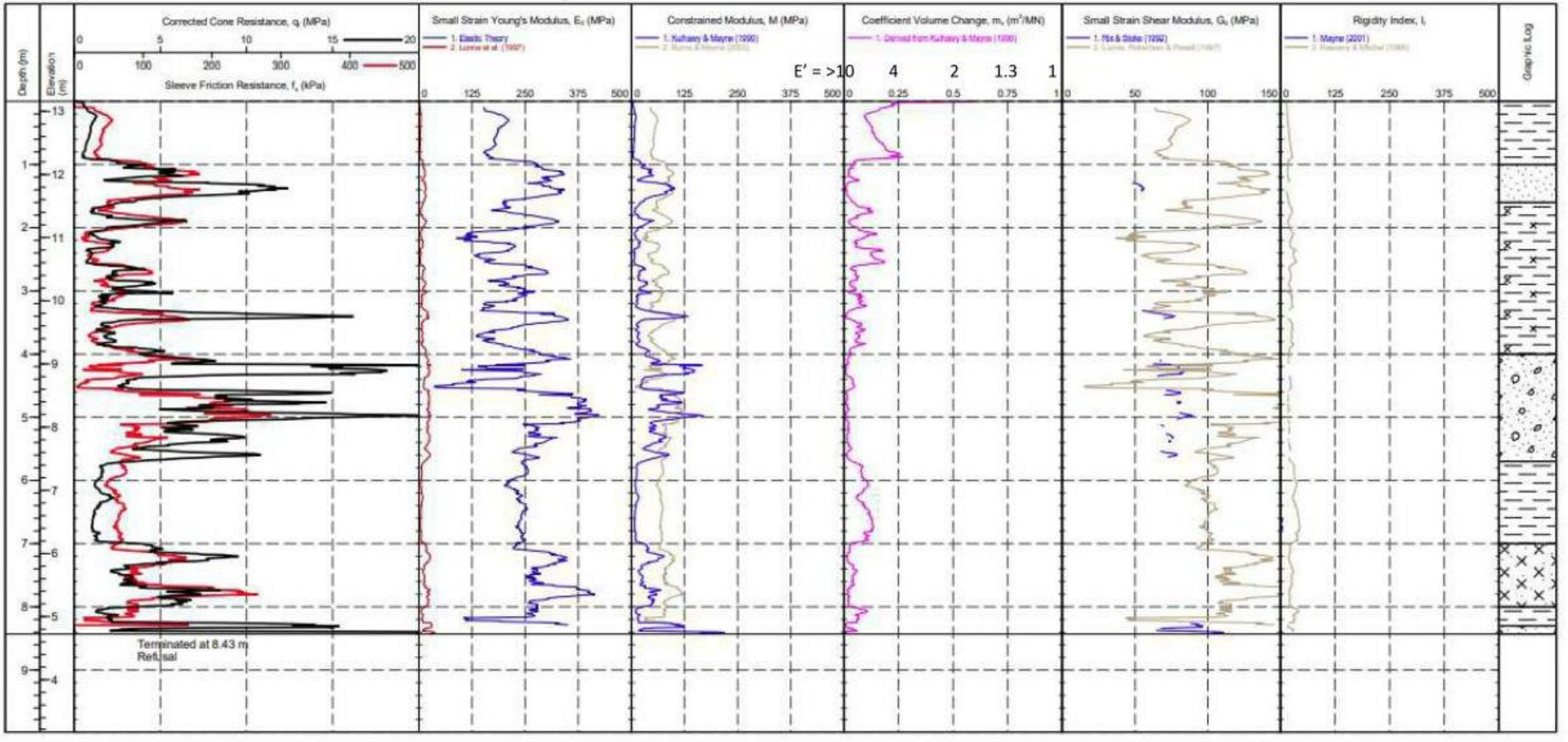
SITE INVESTIGATION Working with: deltasimons

Lincoln | Durham | Norwich | Leeds | Manchester | London

PointID

CPT106

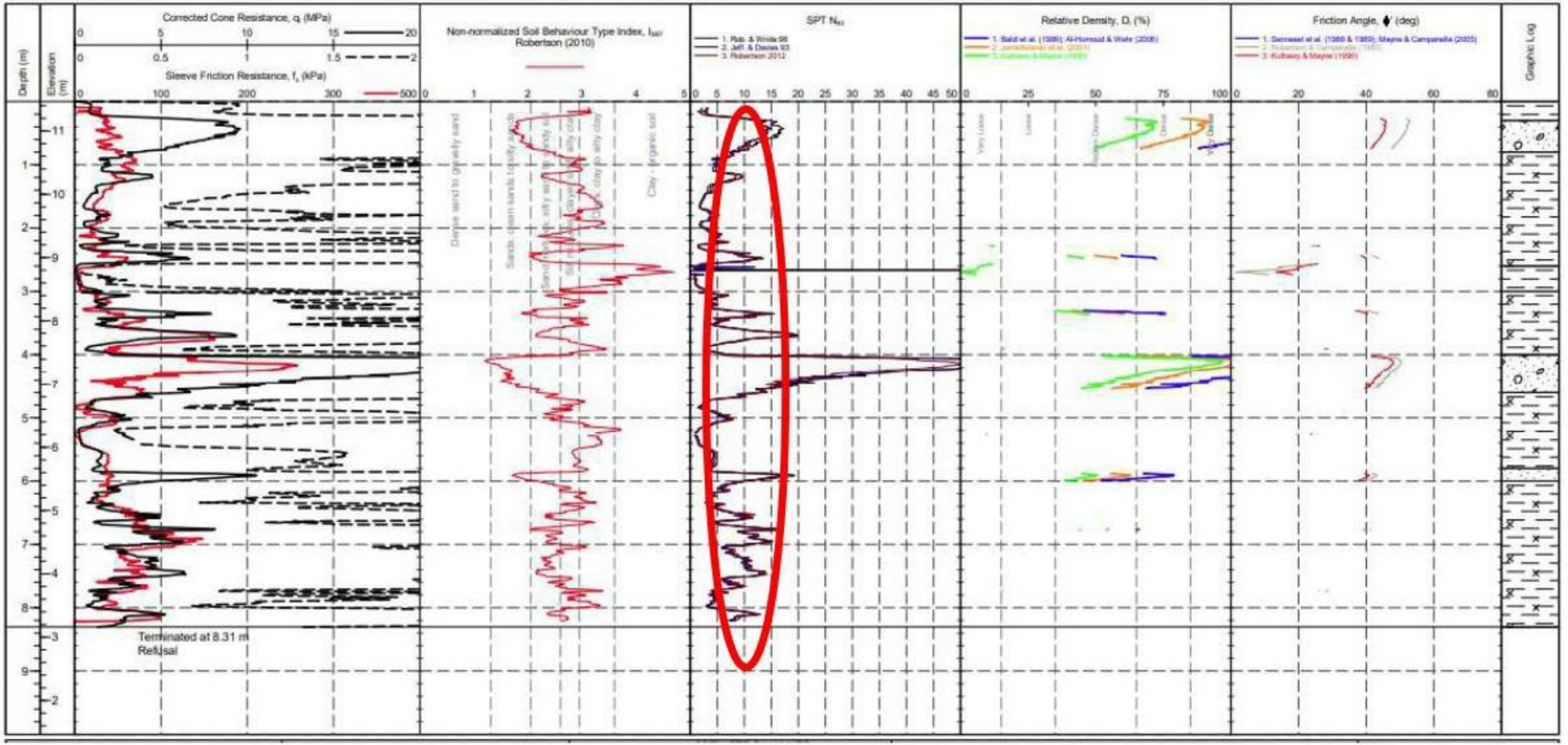
CLIENT : Delta Simons	EASTING : 470193.2 m	Remark:	SHEET : 1 OF 1
PROJECT : Brockhampton	NORTHING : 105762.0 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 13.16 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107B

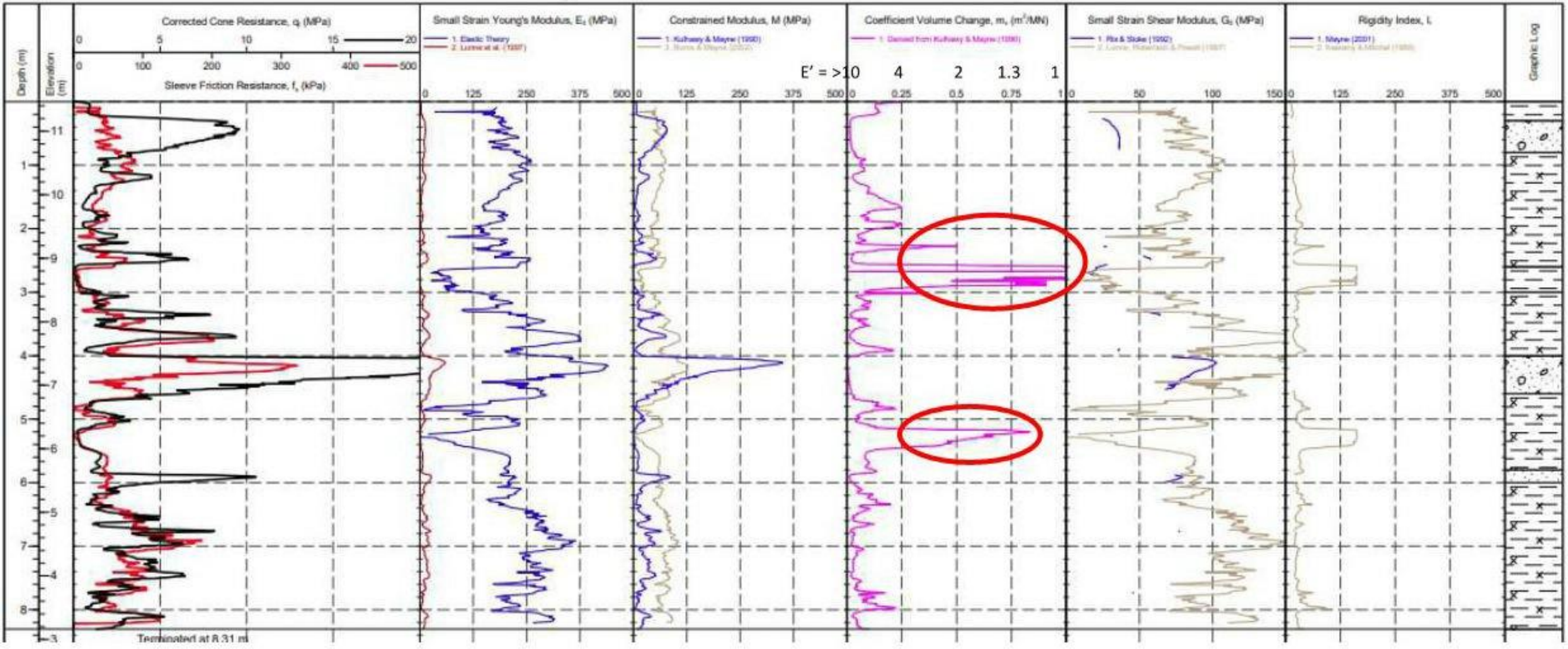
CLIENT : Delta Simons	EASTING : 470238.6 m	Remark:	SHEET : 1 OF 1
PROJECT : Brockhampton	NORTHING : 105760.1 m	Test refused on inclination.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 11.47 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107B

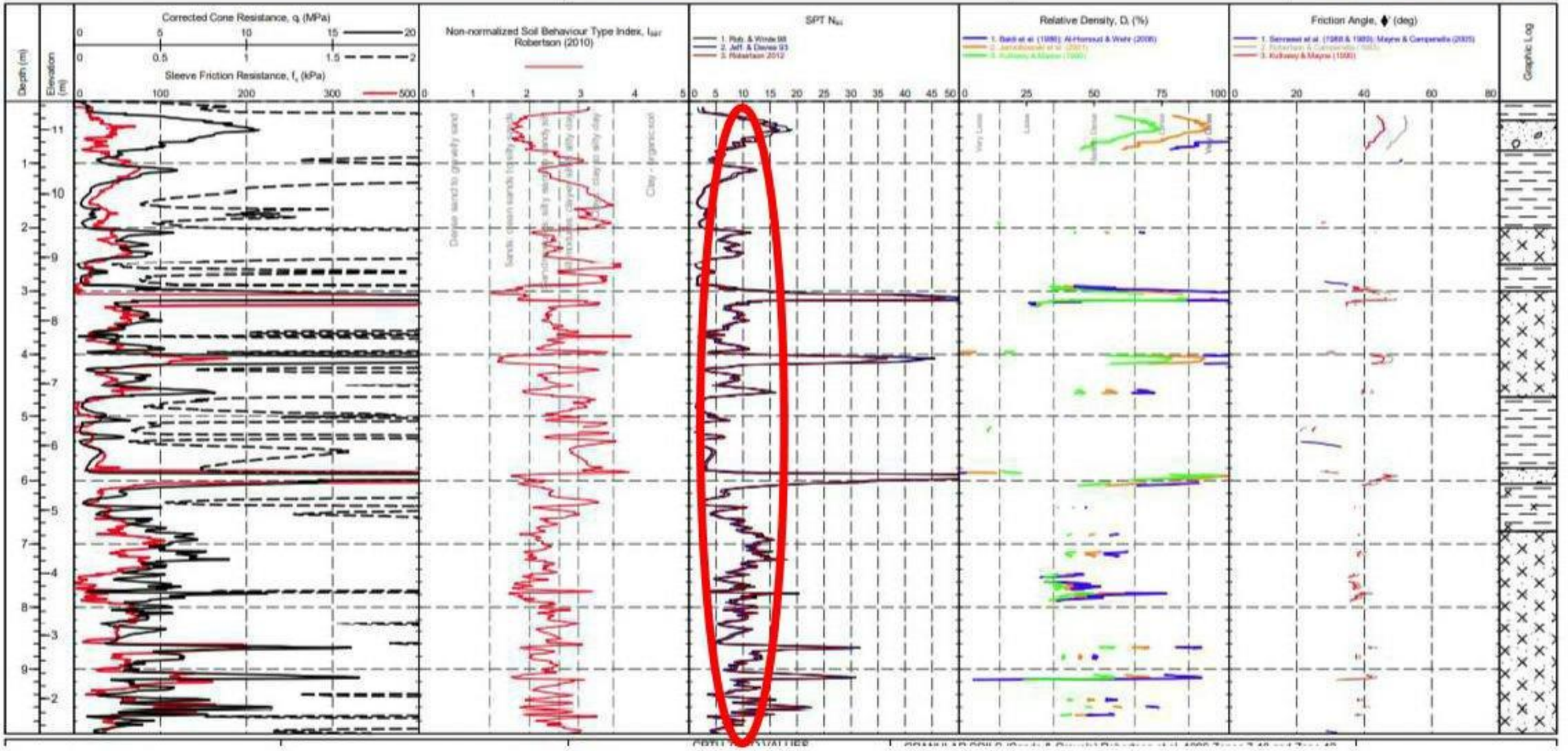
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470238.6 m NORTHING : 105760.1 m ELEVATION : 11.47 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on inclination.	SHEET : 1 OF 1 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107C

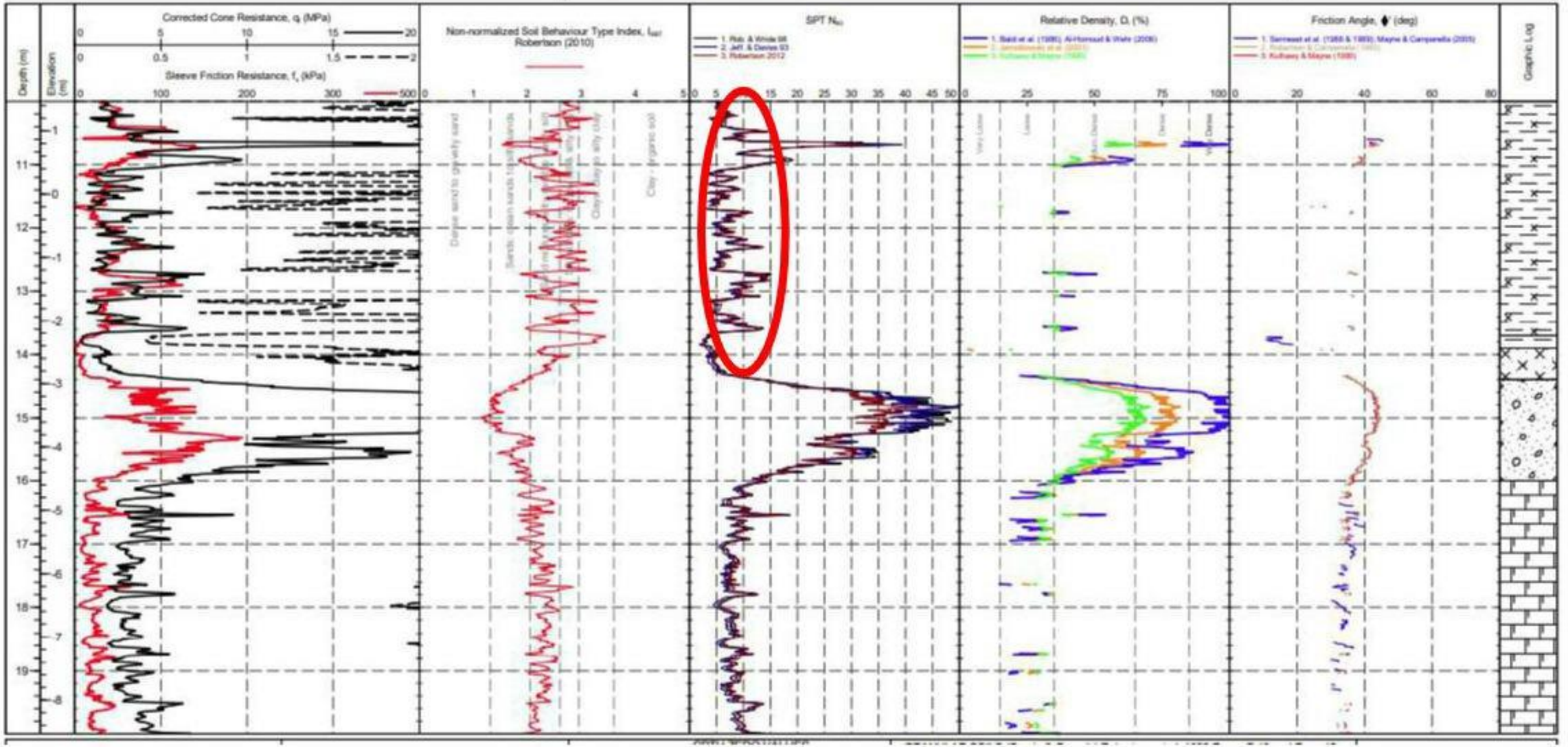
CLIENT : Delta Simons	EASTING : 470238.6 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105760.1 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 11.47 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107C

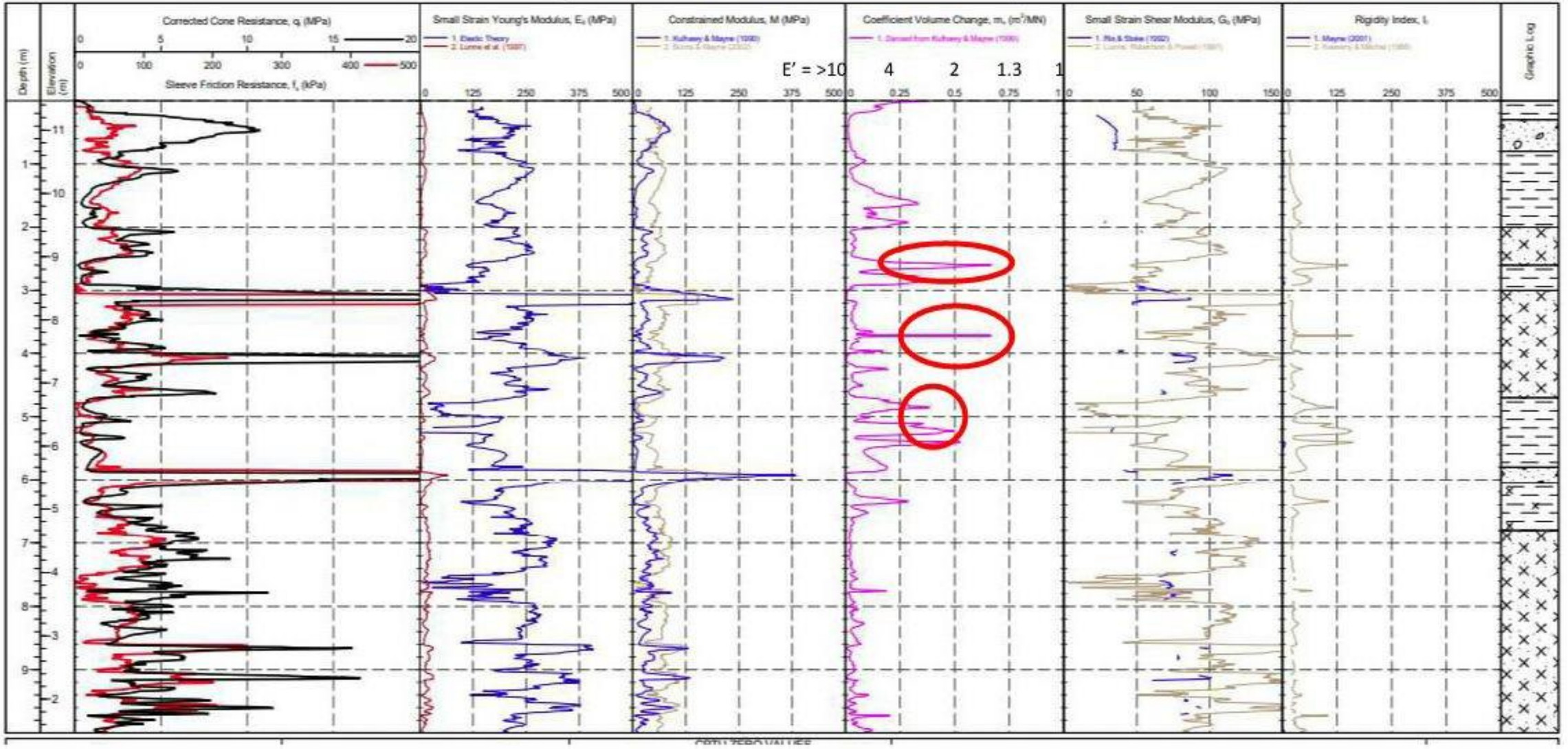
CLIENT : Delta Simons	EASTING : 470238.6 m	Remark:	SHEET : 2 OF 4
PROJECT : Brockhampton	NORTHING : 105760.1 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 11.47 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107C

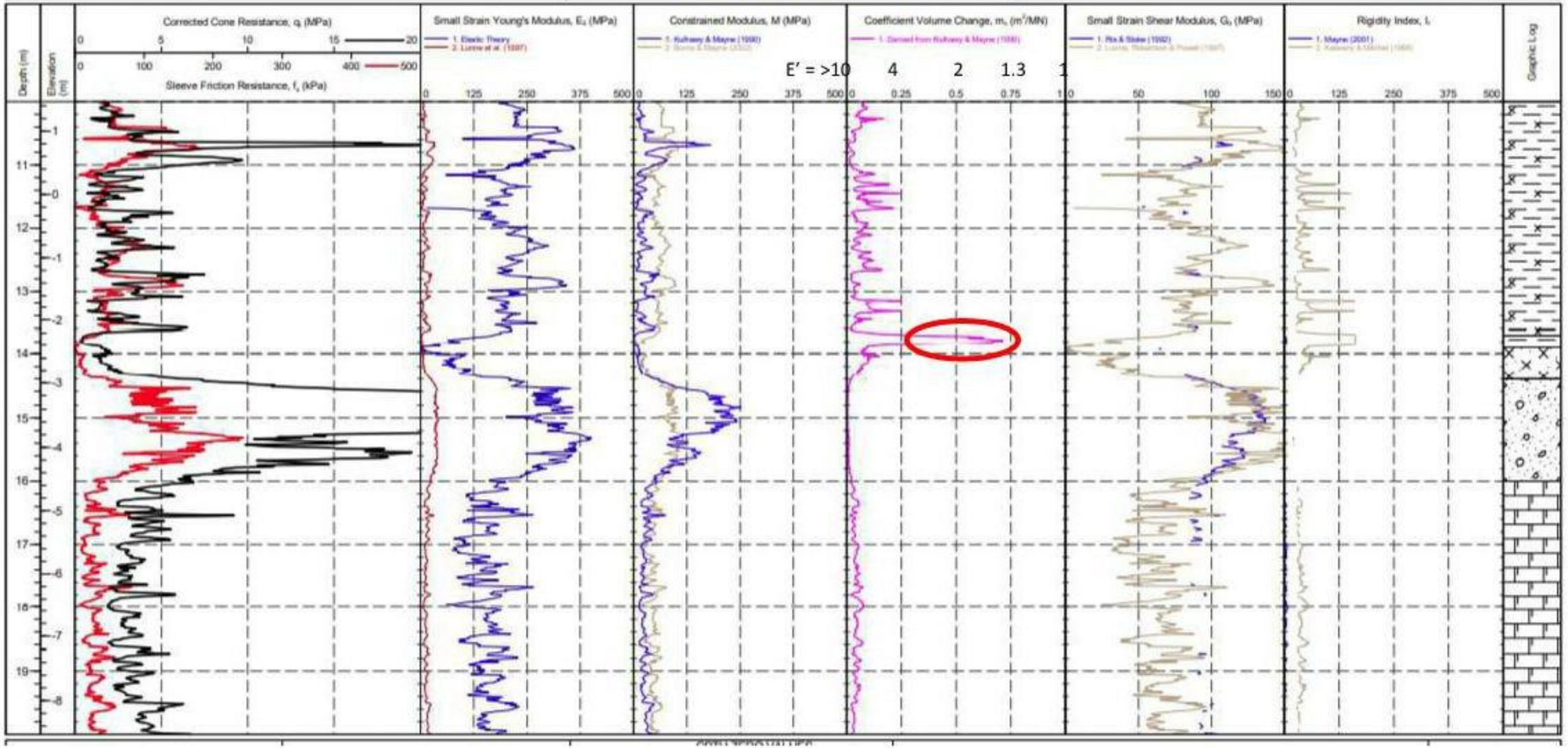
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470238.6 m NORTHING : 105760.1 m ELEVATION : 11.47 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 4 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT107C

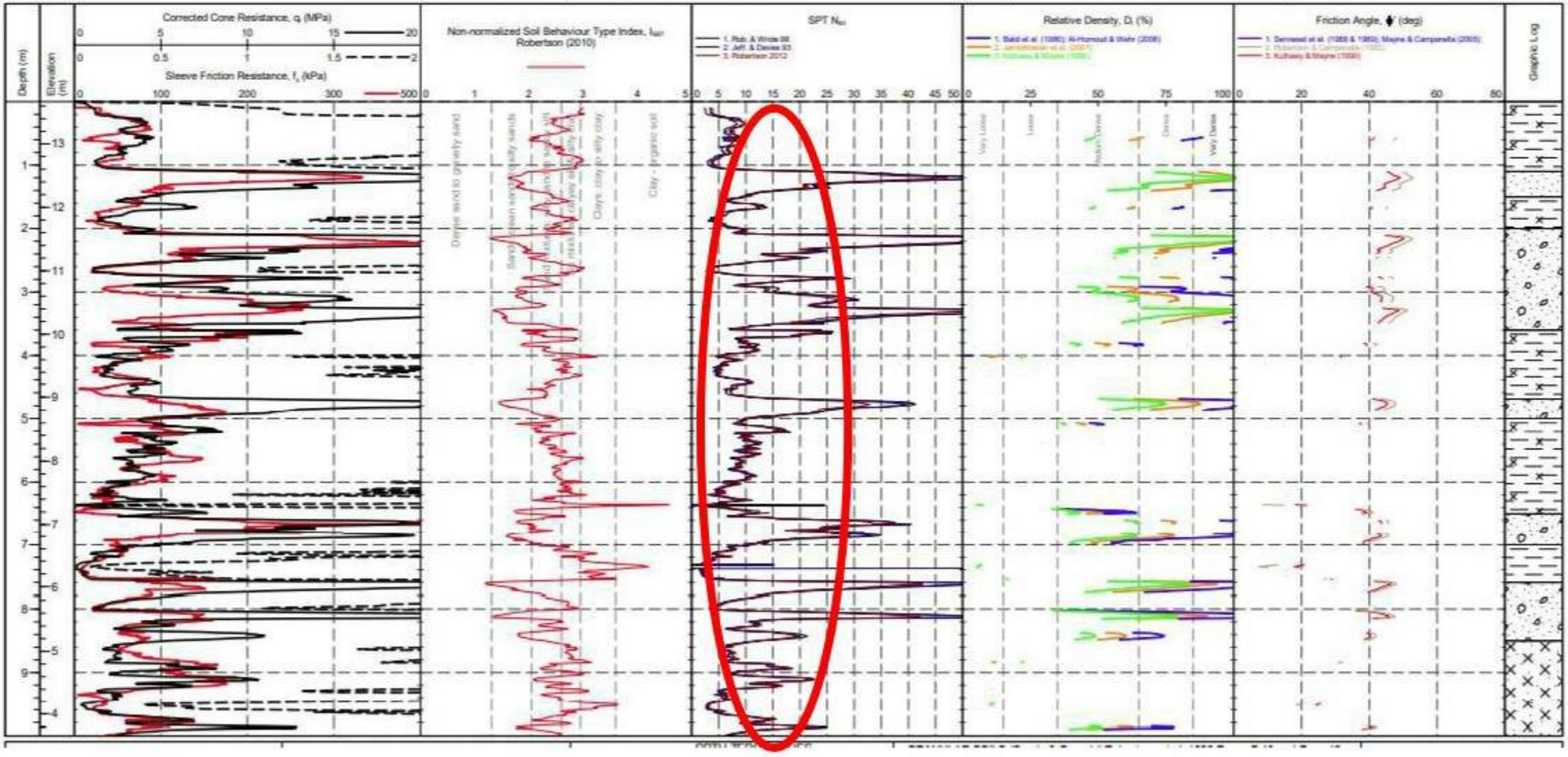
CLIENT : Delta Simons	EASTING : 470238.6 m	Remark:	SHEET : 2 OF 4
PROJECT : Brockhampton	NORTHING : 105760.1 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 11.47 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with: deltasimons

CPT108

CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470233.7 m NORTHING : 105707.5 m ELEVATION : 13.67 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 2 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012

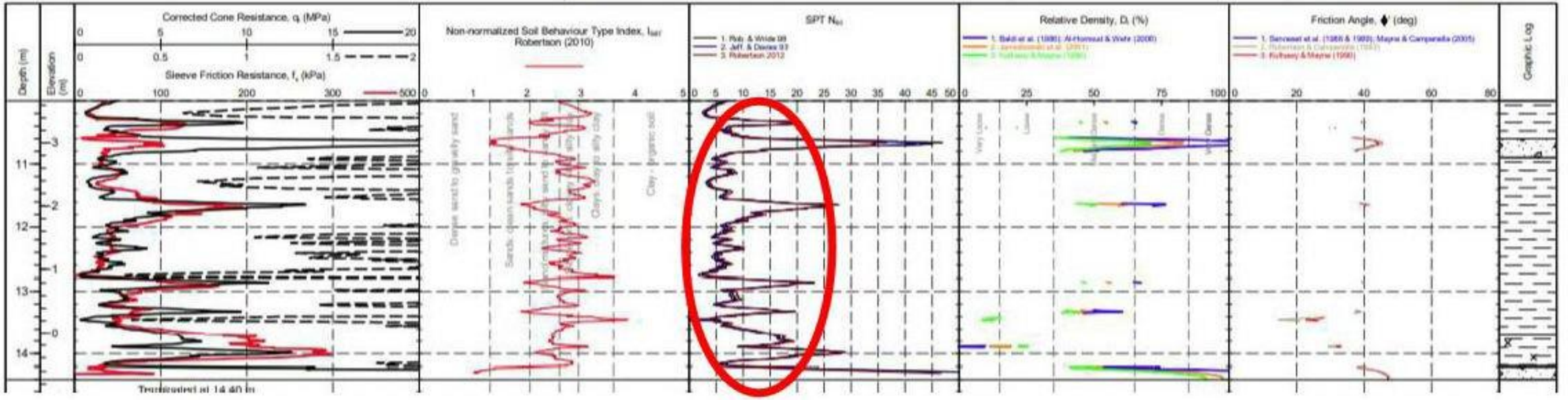


SITE INVESTIGATION Working with: deltasimons

Lincoln | Durham | Norwich | Leeds | Manchester | London

PointID: **CPT108**

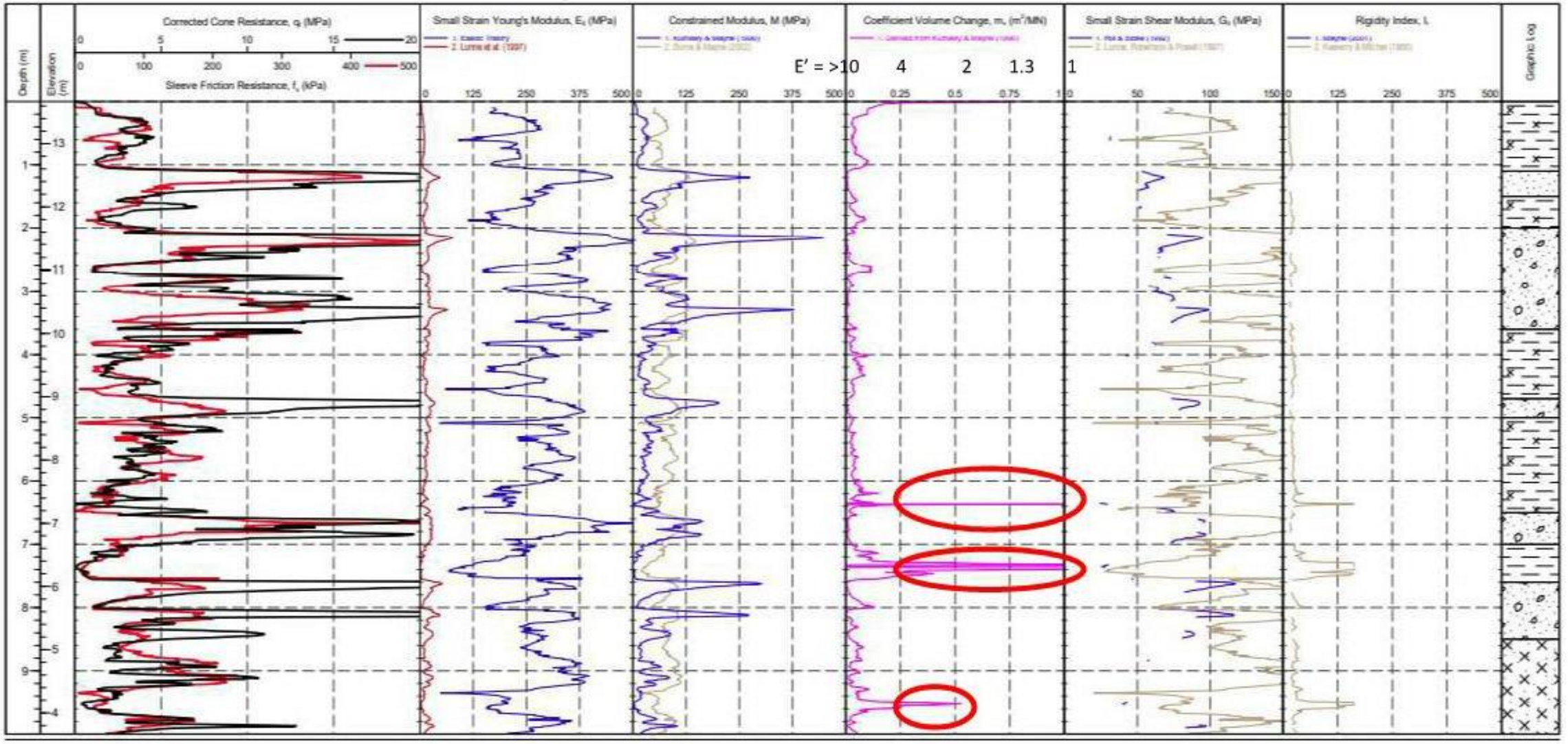
CLIENT : Delta Simons	EASTING : 470233.7 m	Remark:	SHEET : 2 OF 2
PROJECT : Brockhampton	NORTHING : 105707.5 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 13.67 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT108

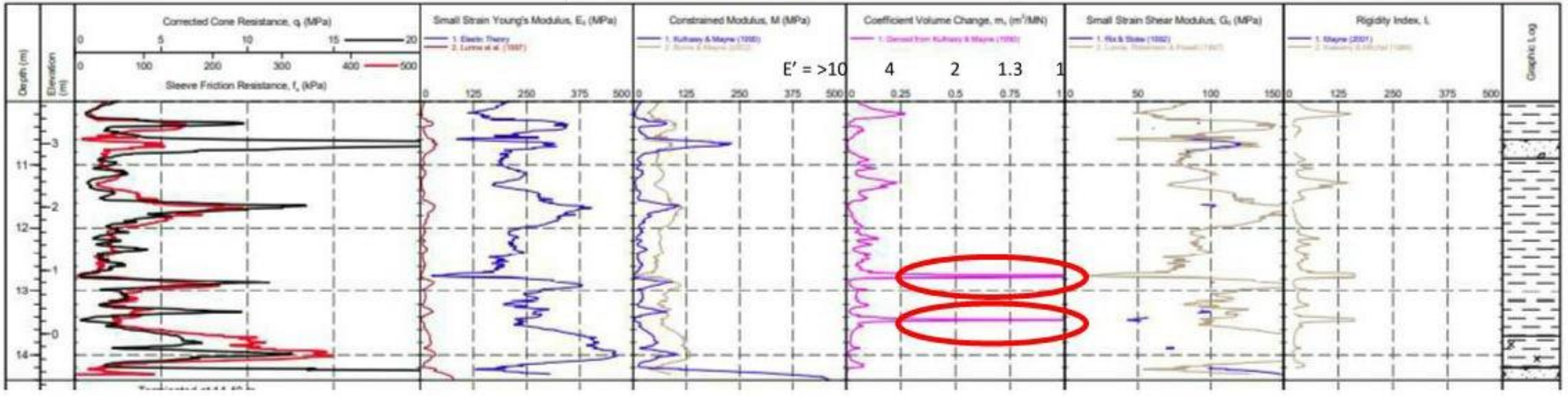
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470233.7 m NORTHING : 105707.5 m ELEVATION : 13.67 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 2 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT108

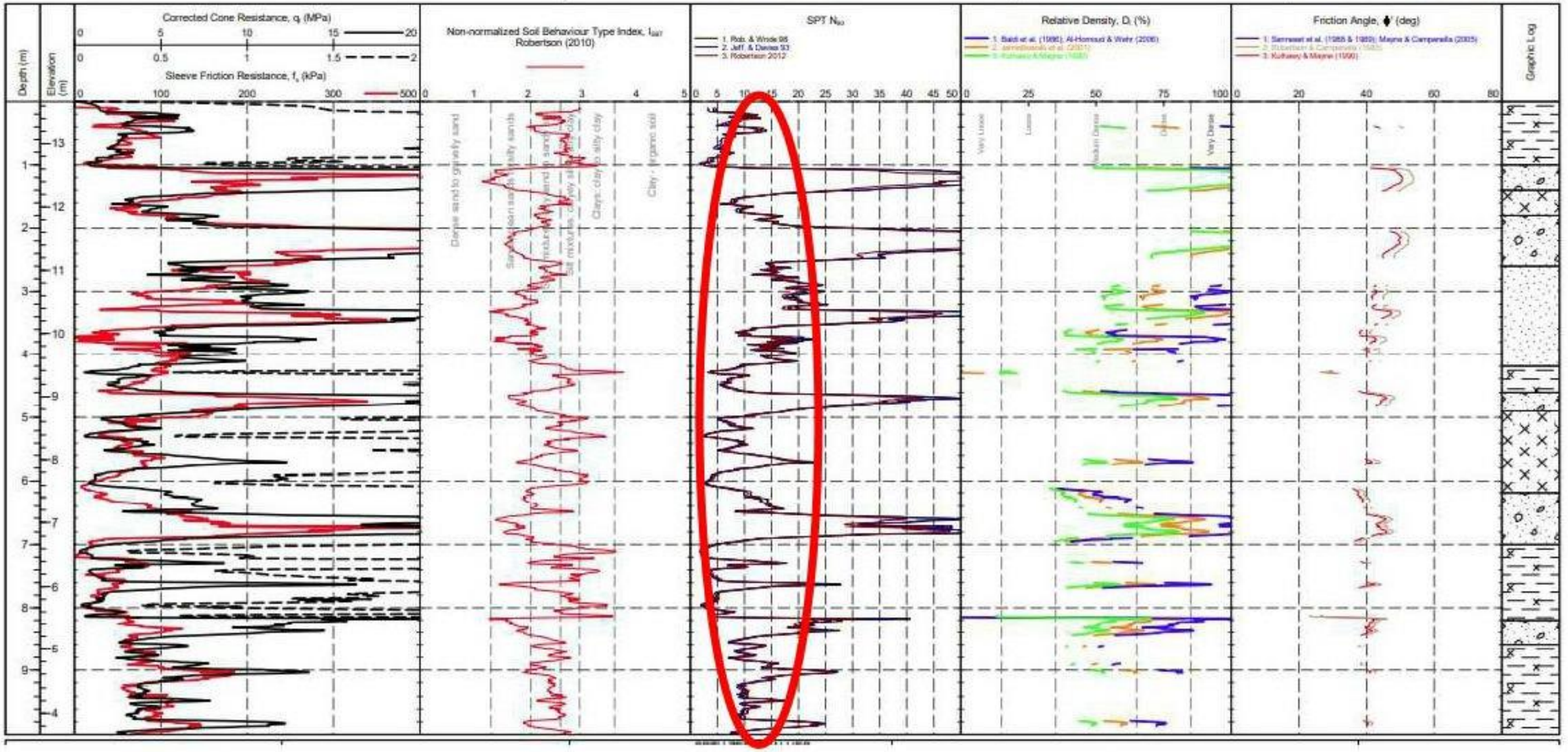
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470233.7 m NORTHING : 105707.5 m ELEVATION : 13.67 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 2 OF 2 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT108A

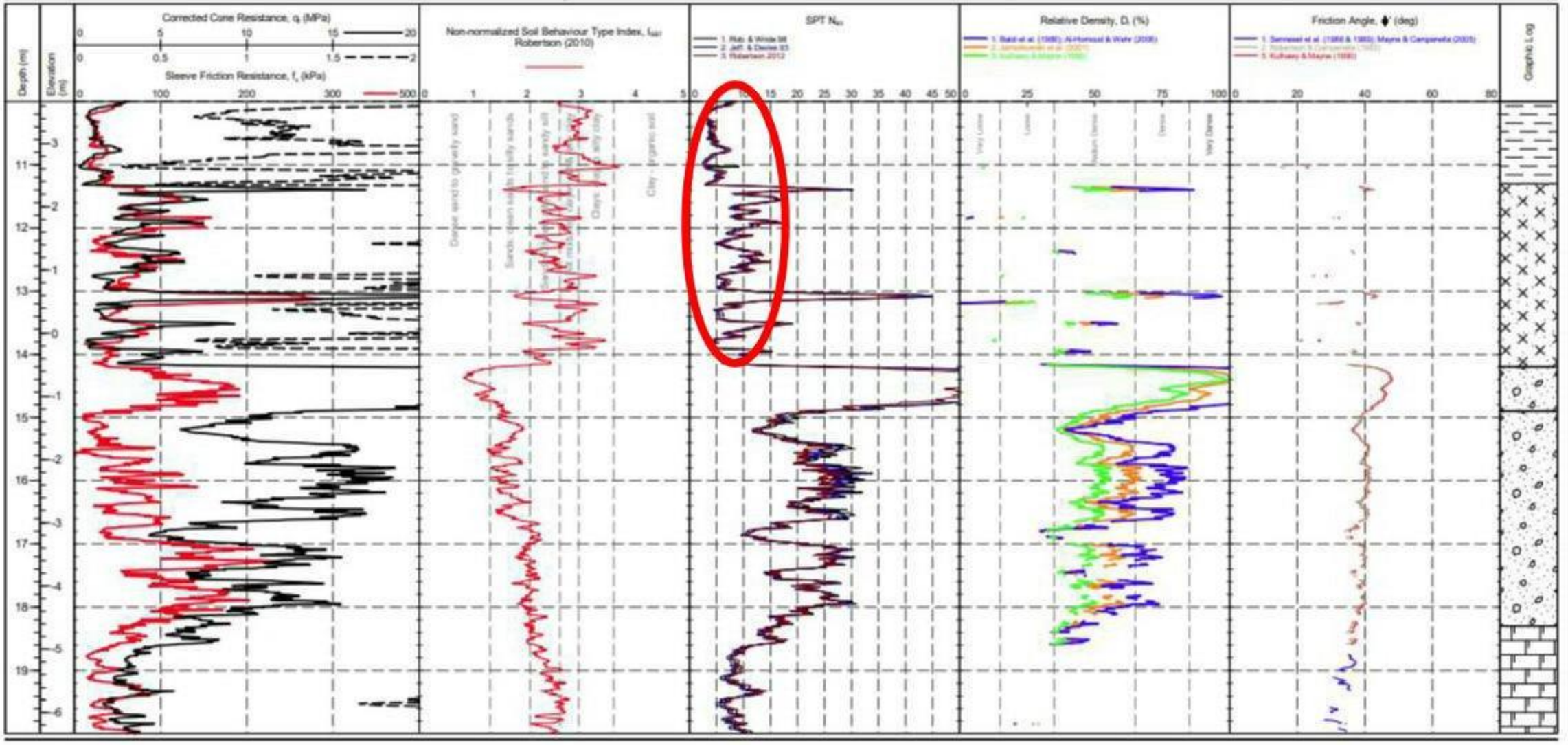
CLIENT : Delta Simons	EASTING : 470233.7 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105707.5 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 13.67 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT108A

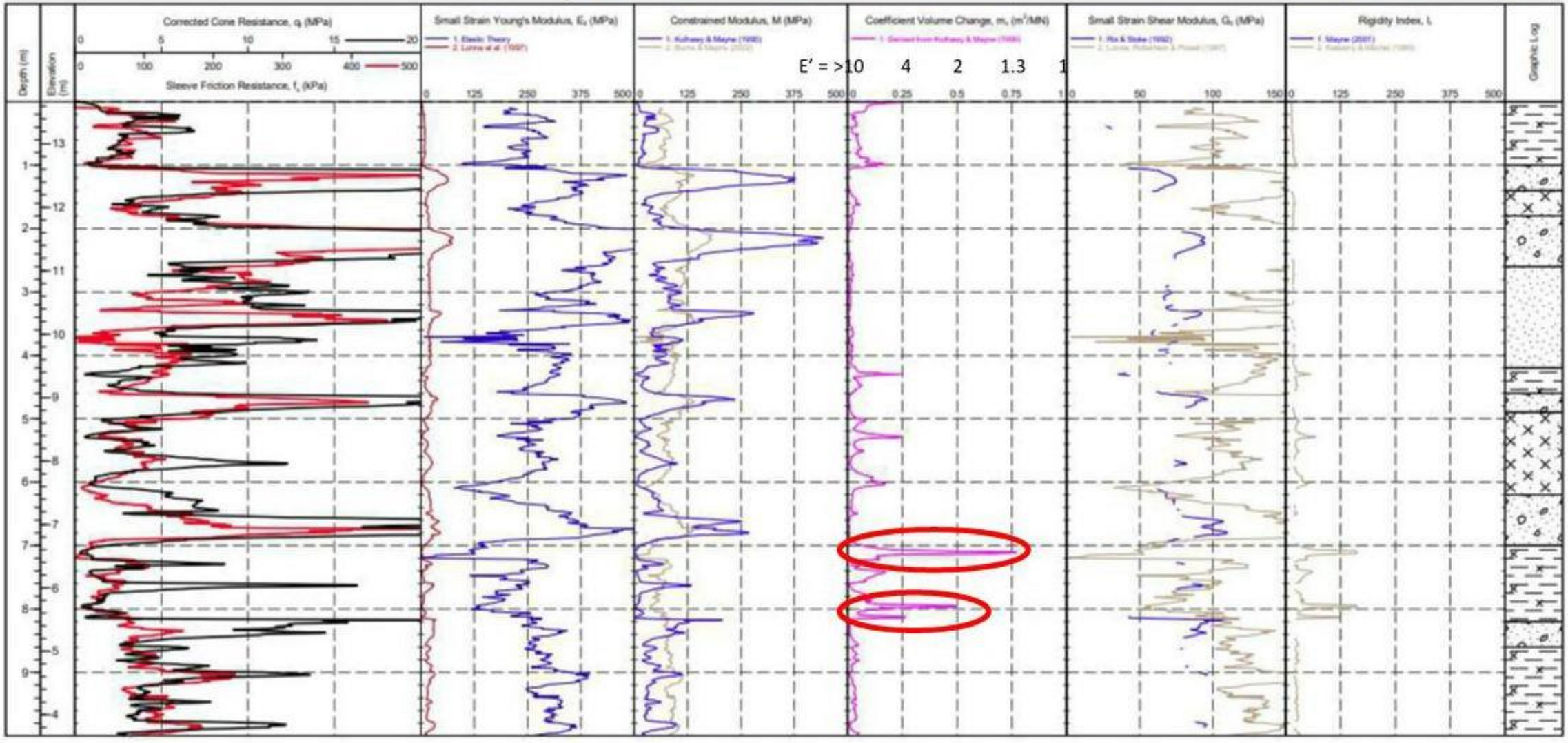
CLIENT : Delta Simons	EASTING : 470233.7 m	Remark:	SHEET : 2 OF 4
PROJECT : Brockhampton	NORTHING : 105707.5 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 13.67 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT108A

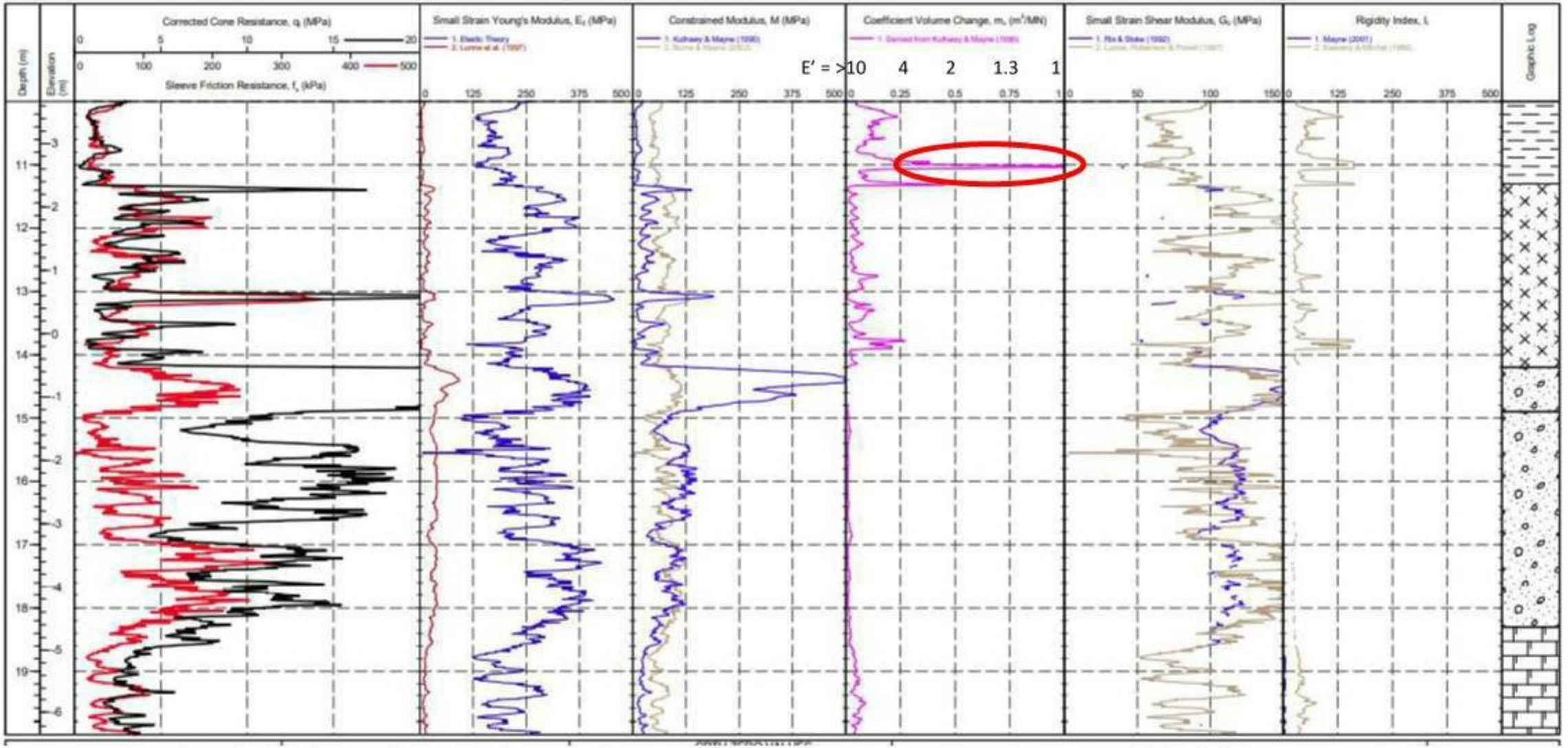
CLIENT : Delta Simons	EASTING : 470233.7 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105707.5 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 13.67 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with: deltasimons

PointID: **CPT108A**

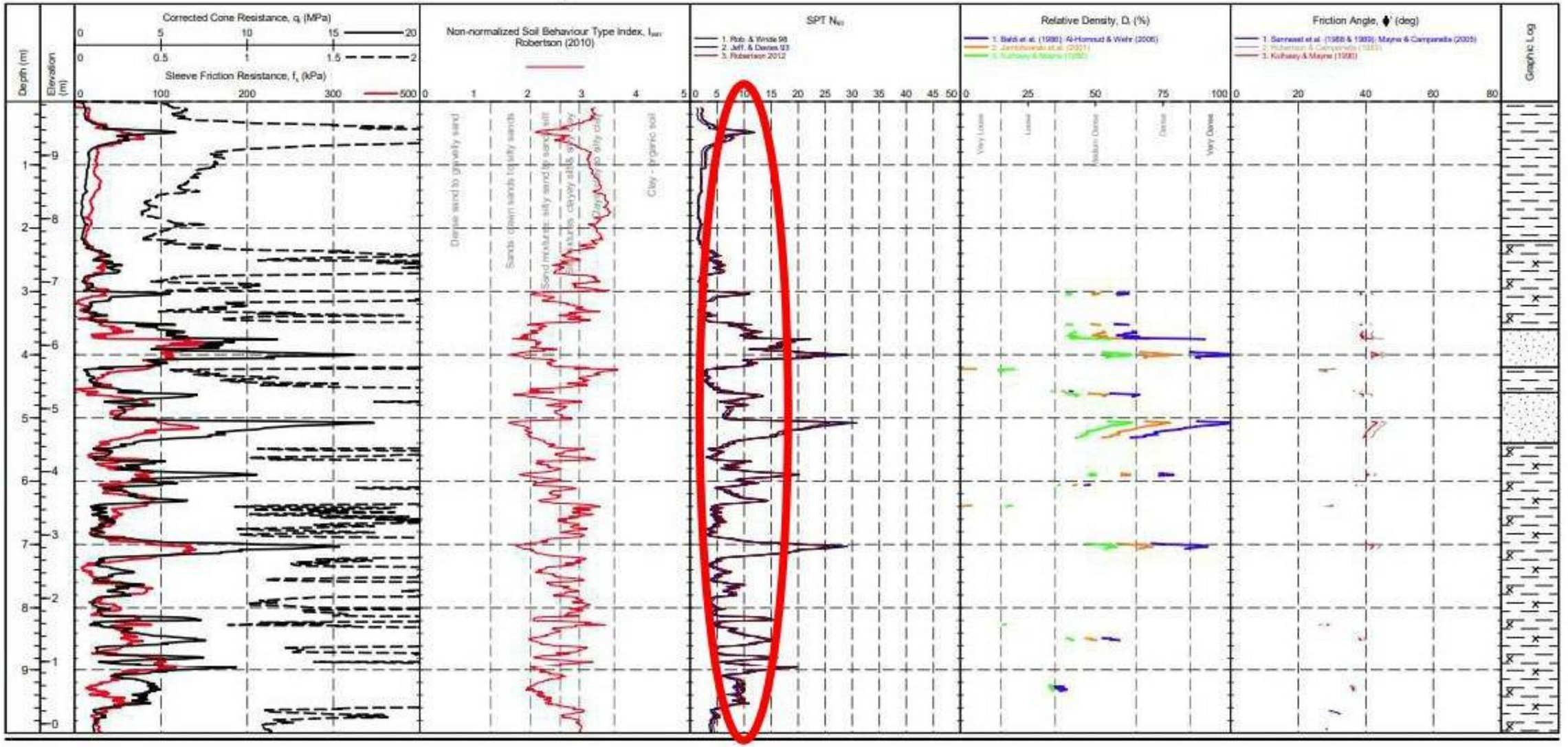
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470233.7 m NORTHING : 105707.5 m ELEVATION : 13.67 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 2 OF 4 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT109

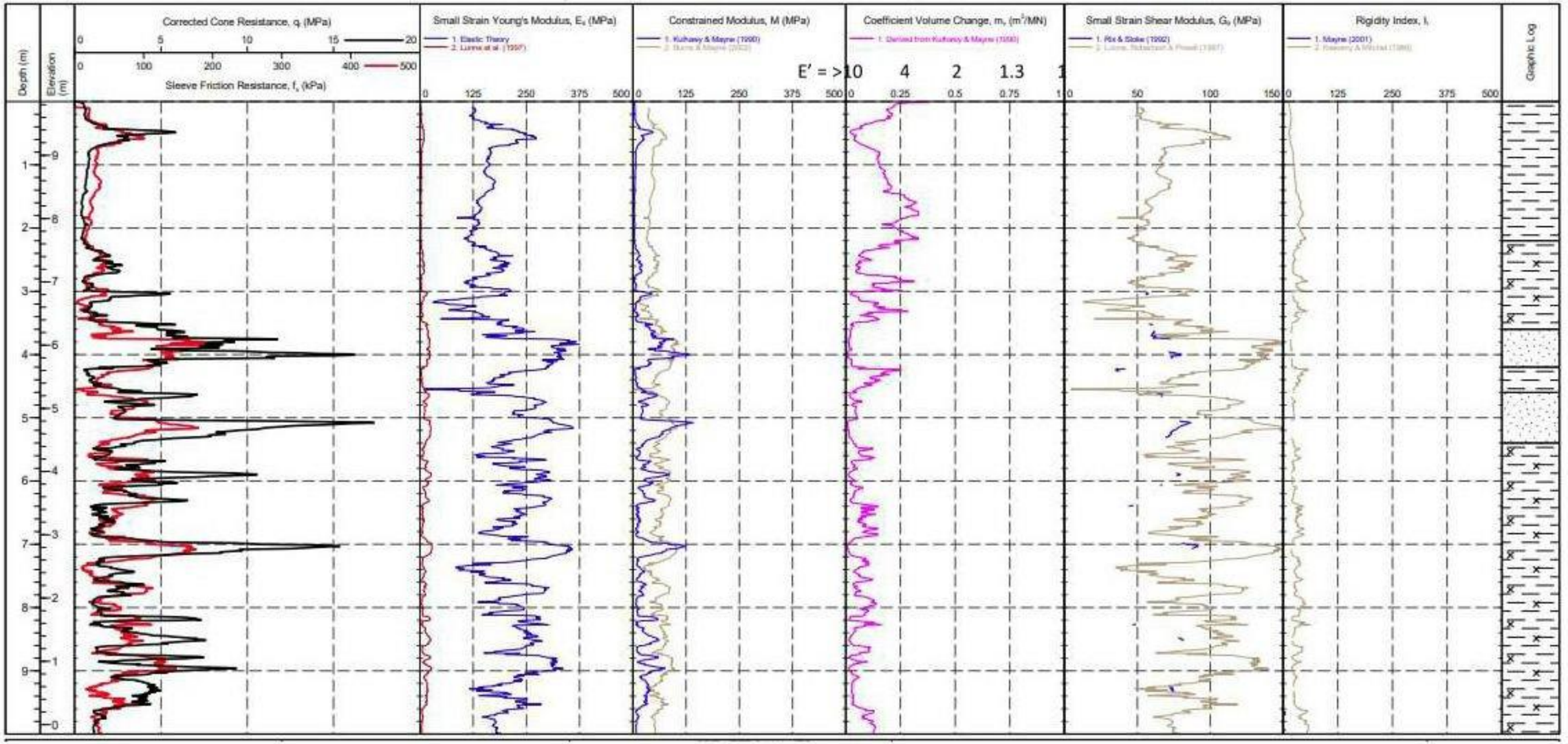
CLIENT : Delta Simons	EASTING : 470148.8 m	Remark:	SHEET : 1 OF 3
PROJECT : Brockhampton	NORTHING : 105718.3 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 9.85 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT109

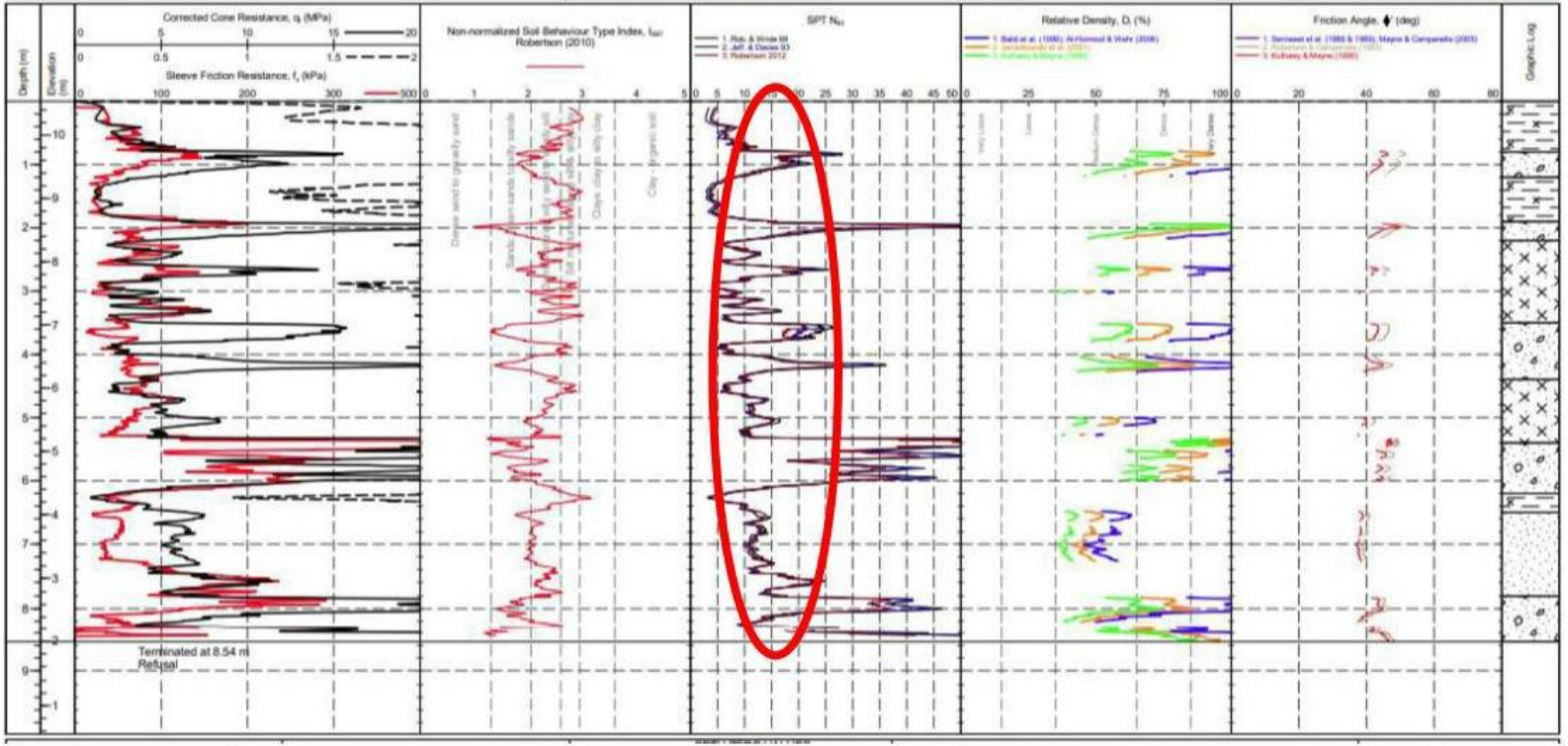
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470148.8 m NORTHING : 105718.3 m ELEVATION : 9.85 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 3 STATUS : Final TEST DATE : 30/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT110

CLIENT : Delta Simons	EASTING : 470271.9 m	Remark:	SHEET : 1 OF 1
PROJECT : Brockhampton	NORTHING : 105676.7 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.53 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012

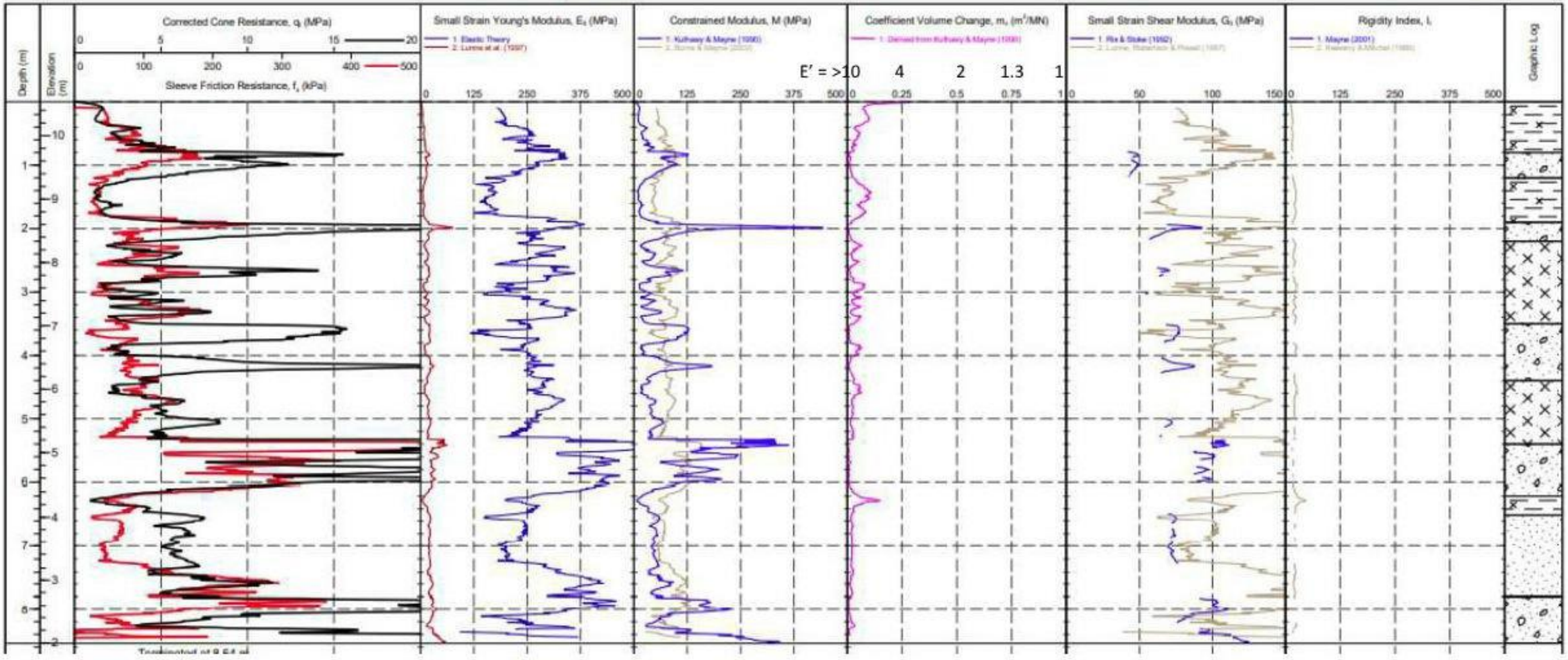


IN SITU
SITE INVESTIGATION Working with: deltasimons

Lincoln | Durham | Norwich | Leeds | Manchester | London

PointID
CPT110

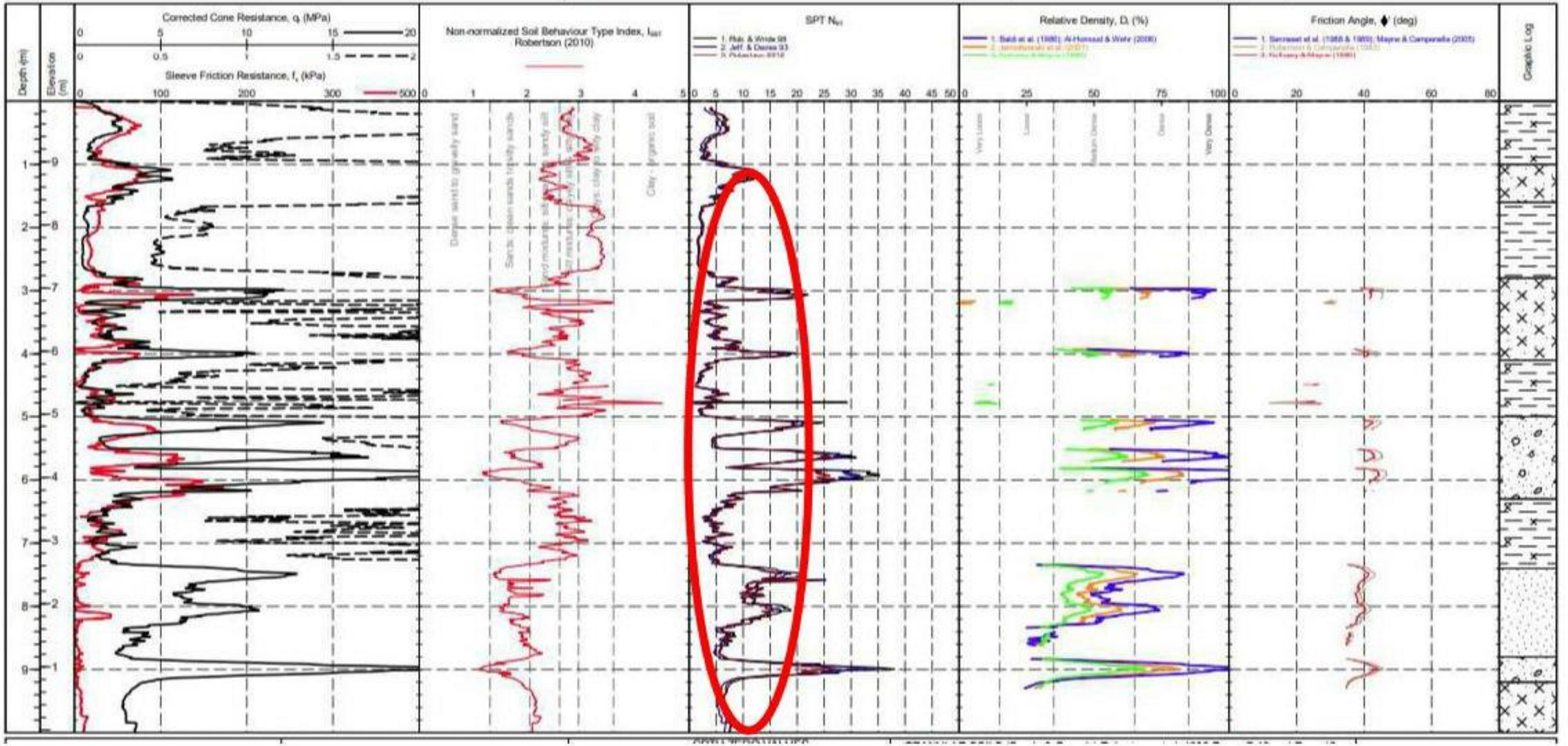
CLIENT : Delta Simons	EASTING : 470271.9 m	Remark:	SHEET : 1 OF 1
PROJECT : Brockhampton	NORTHING : 105676.7 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.53 m OD		TEST DATE : 30/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with: deltasimons

PointID: **CPT111**

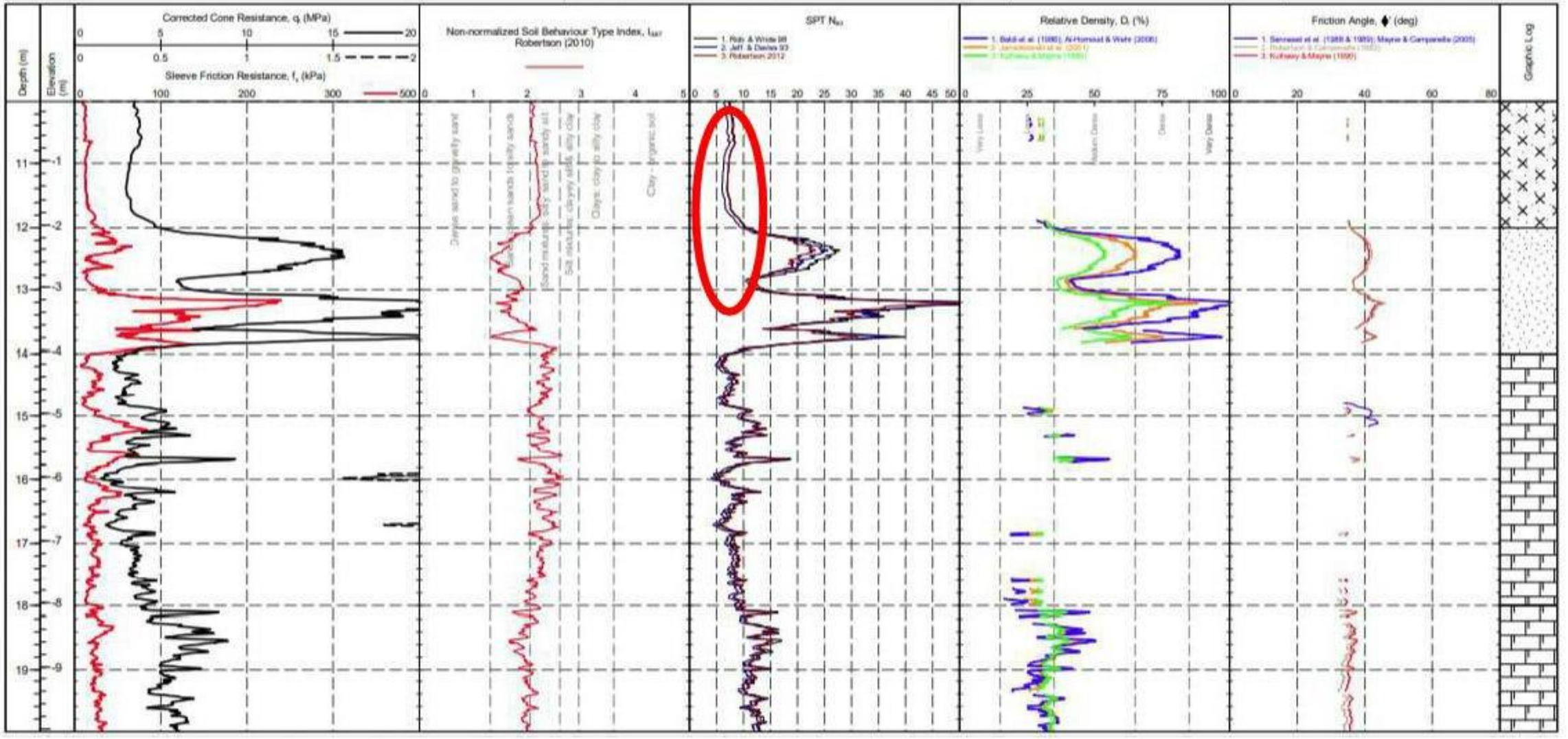
CLIENT : Delta Simons	EASTING : 470097.5 m	Remark:	SHEET : 1 OF 3
PROJECT : Brockhampton	NORTHING : 105621.3 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 9.96 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT111

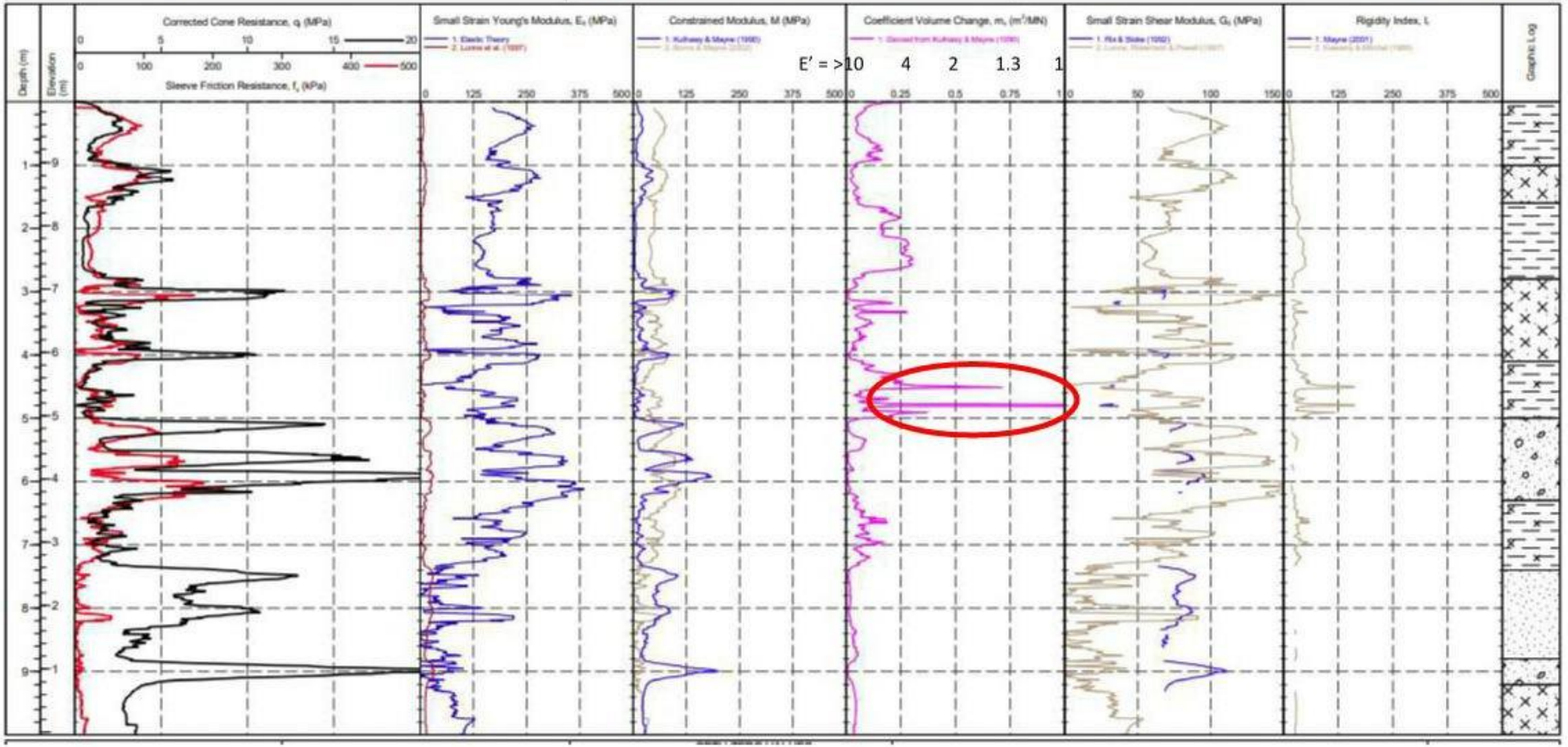
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470097.5 m NORTHING : 105621.3 m ELEVATION : 9.96 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 2 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT111

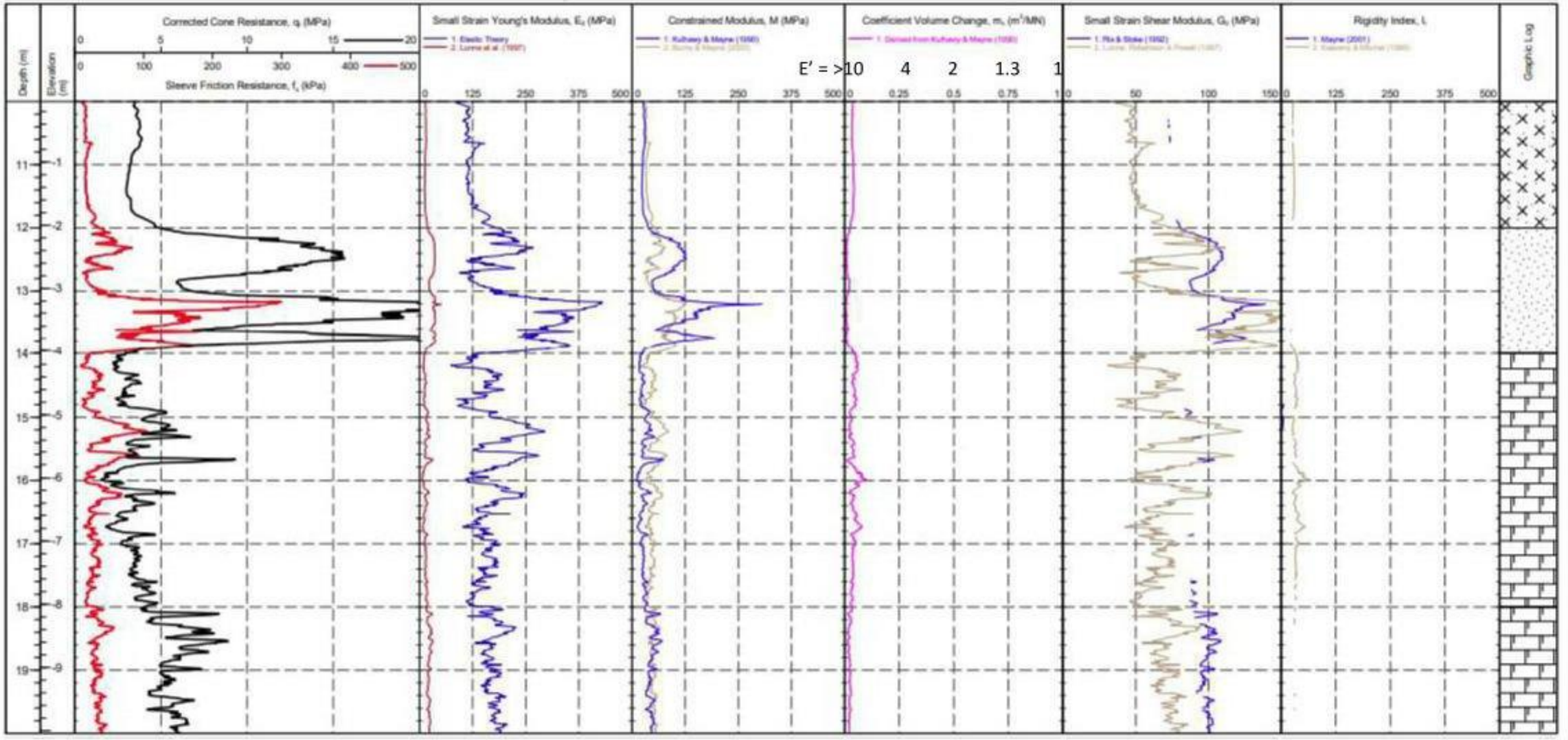
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470097.5 m NORTHING : 105621.3 m ELEVATION : 9.96 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT111

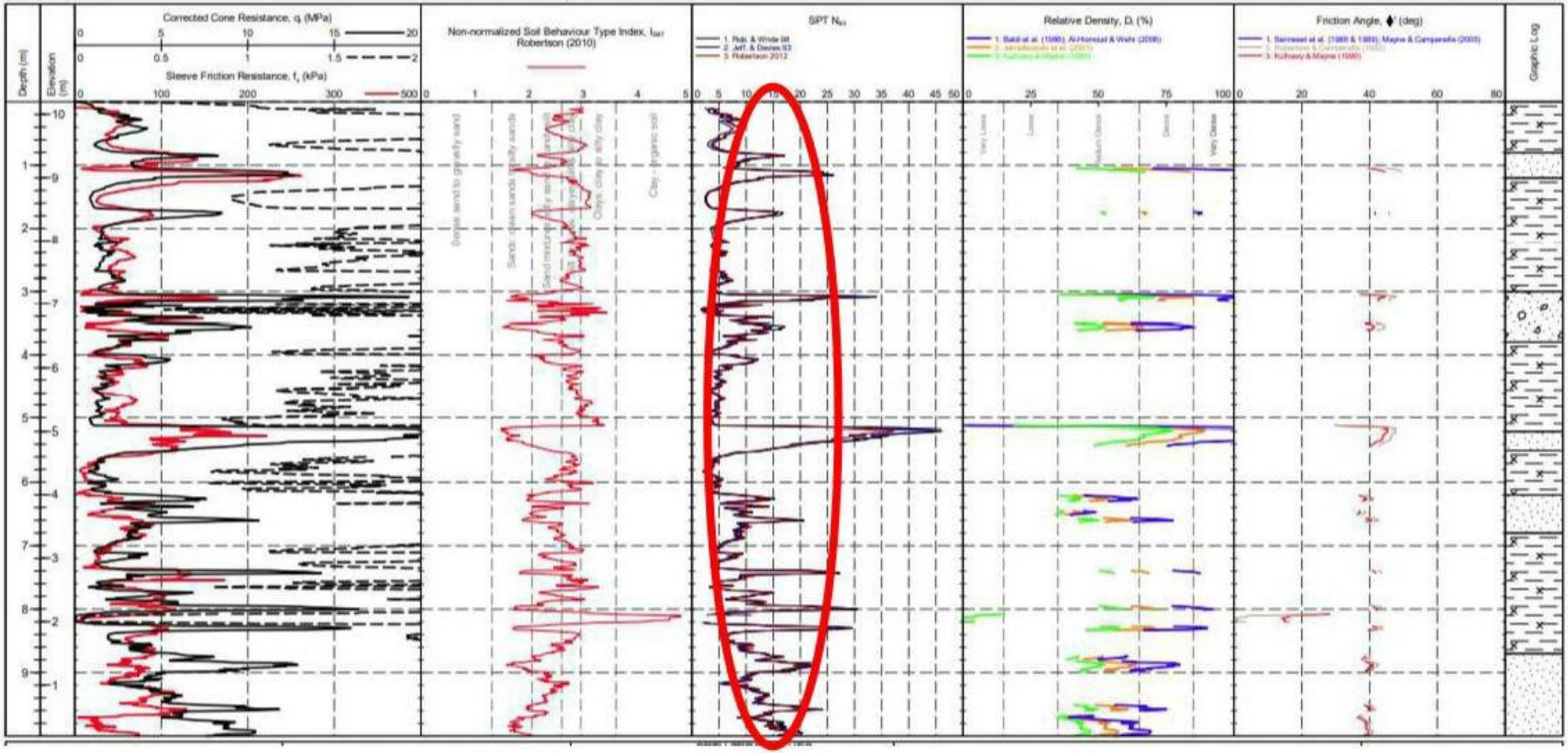
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470097.5 m NORTHING : 105621.3 m ELEVATION : 9.96 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 2 OF 3 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT112

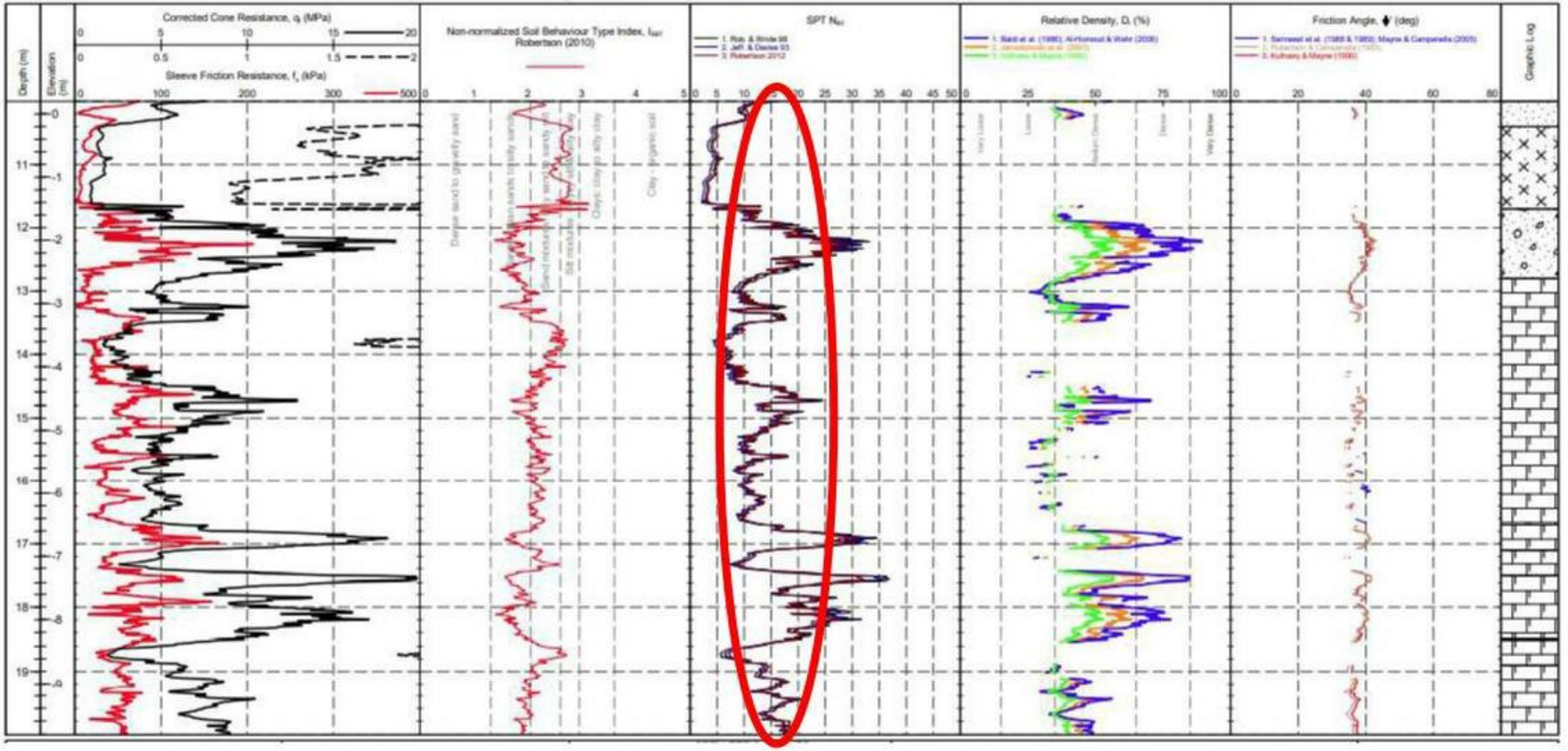
CLIENT : Delta Simons	EASTING : 470029.3 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105595.0 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.20 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



SITE INVESTIGATION Working with: deltasimons

PointID: **CPT112**

CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470029.3 m NORTHING : 105595.0 m ELEVATION : 10.20 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 2 OF 4 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012

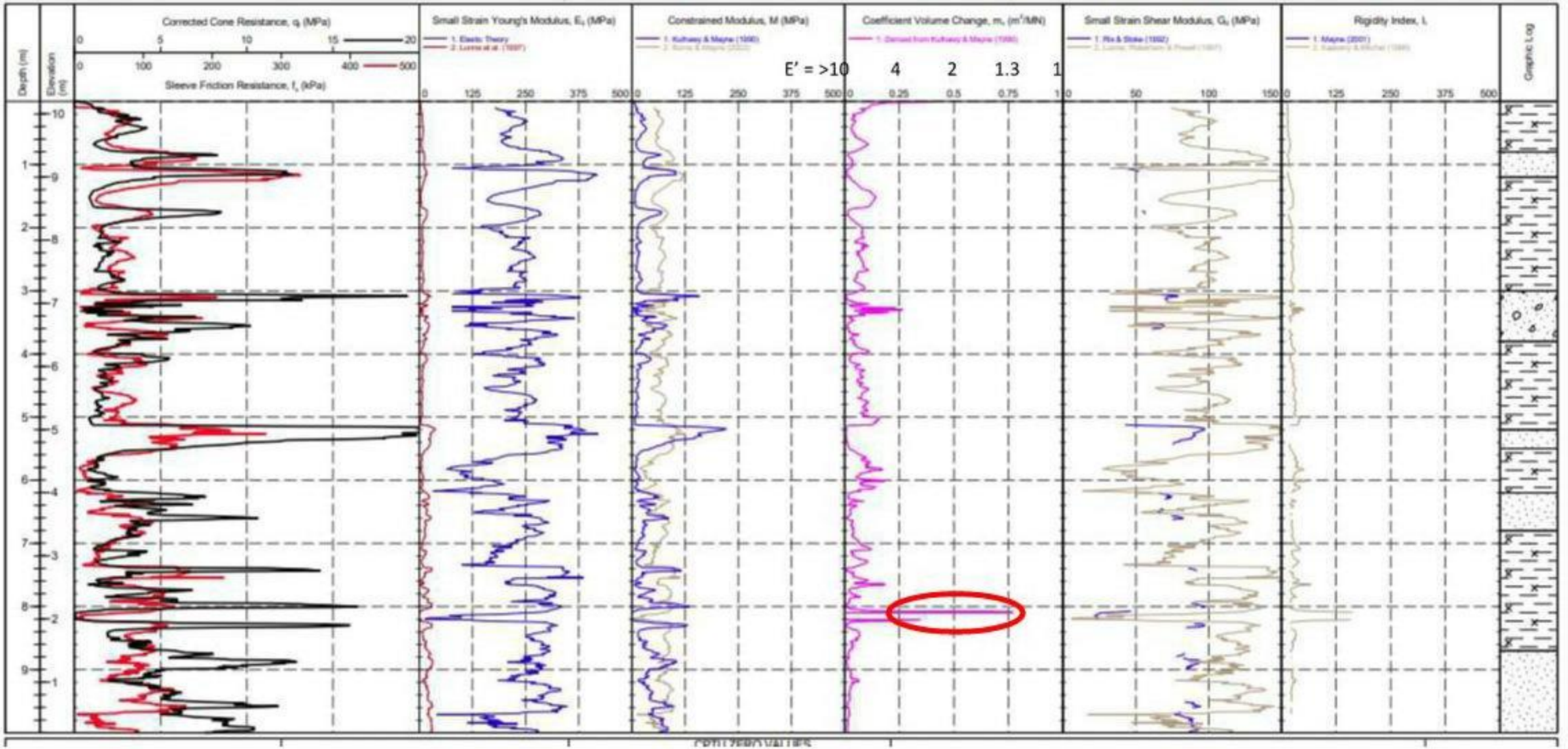


IN SITU
SITE INVESTIGATION Working with: deltasimons

CPT LOG 05

PointID
CPT112

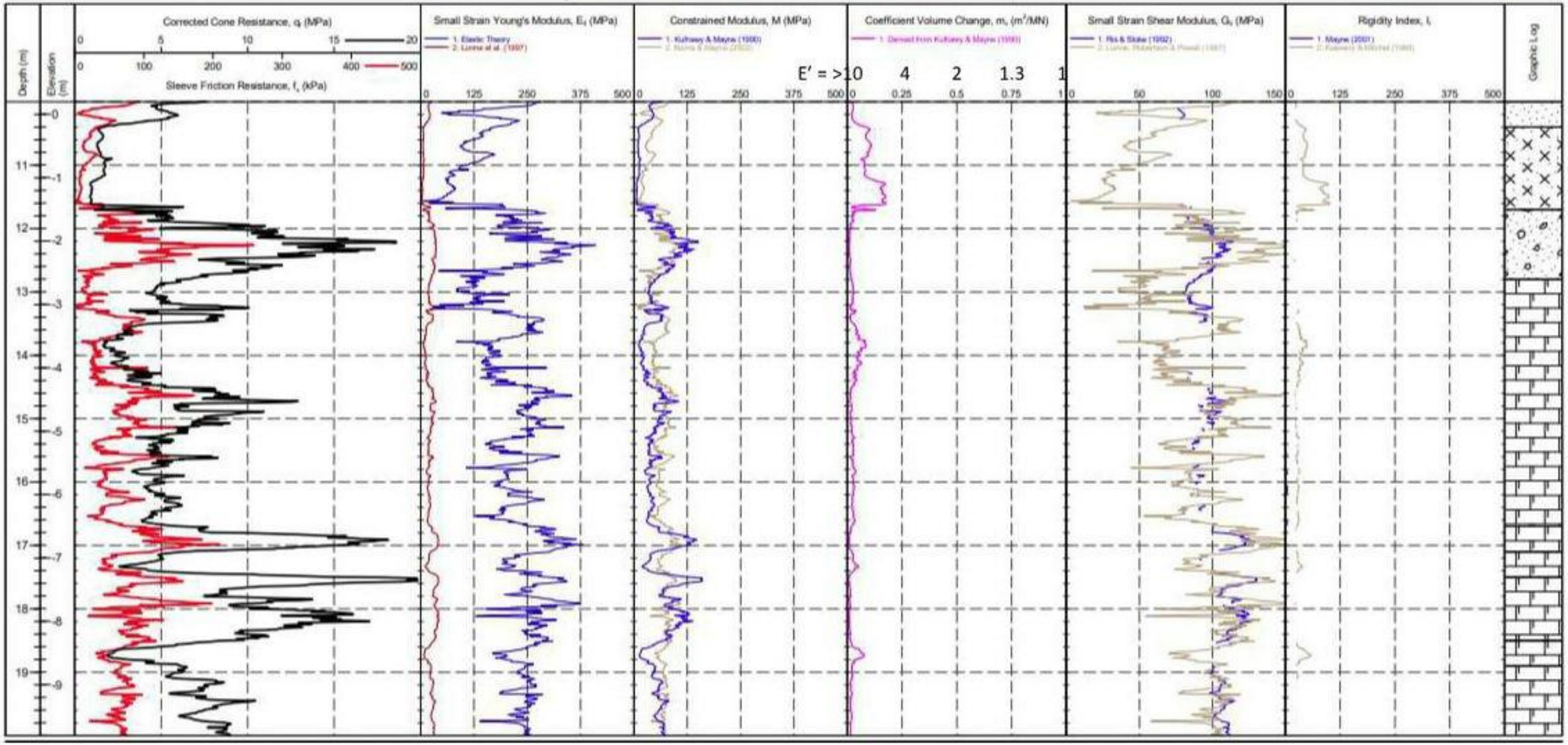
CLIENT : Delta Simons PROJECT : Brockhampton LOCATION : Brockhampton PROJECT No. : 1210220	EASTING : 470029.3 m NORTHING : 105595.0 m ELEVATION : 10.20 m OD CHECKED BY : LD TERMINATION REASON : Refusal	Remark: Test refused on total pressure.	SHEET : 1 OF 4 STATUS : Final TEST DATE : 29/03/2021 PLOT DATE : 25/05/2021 METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT112

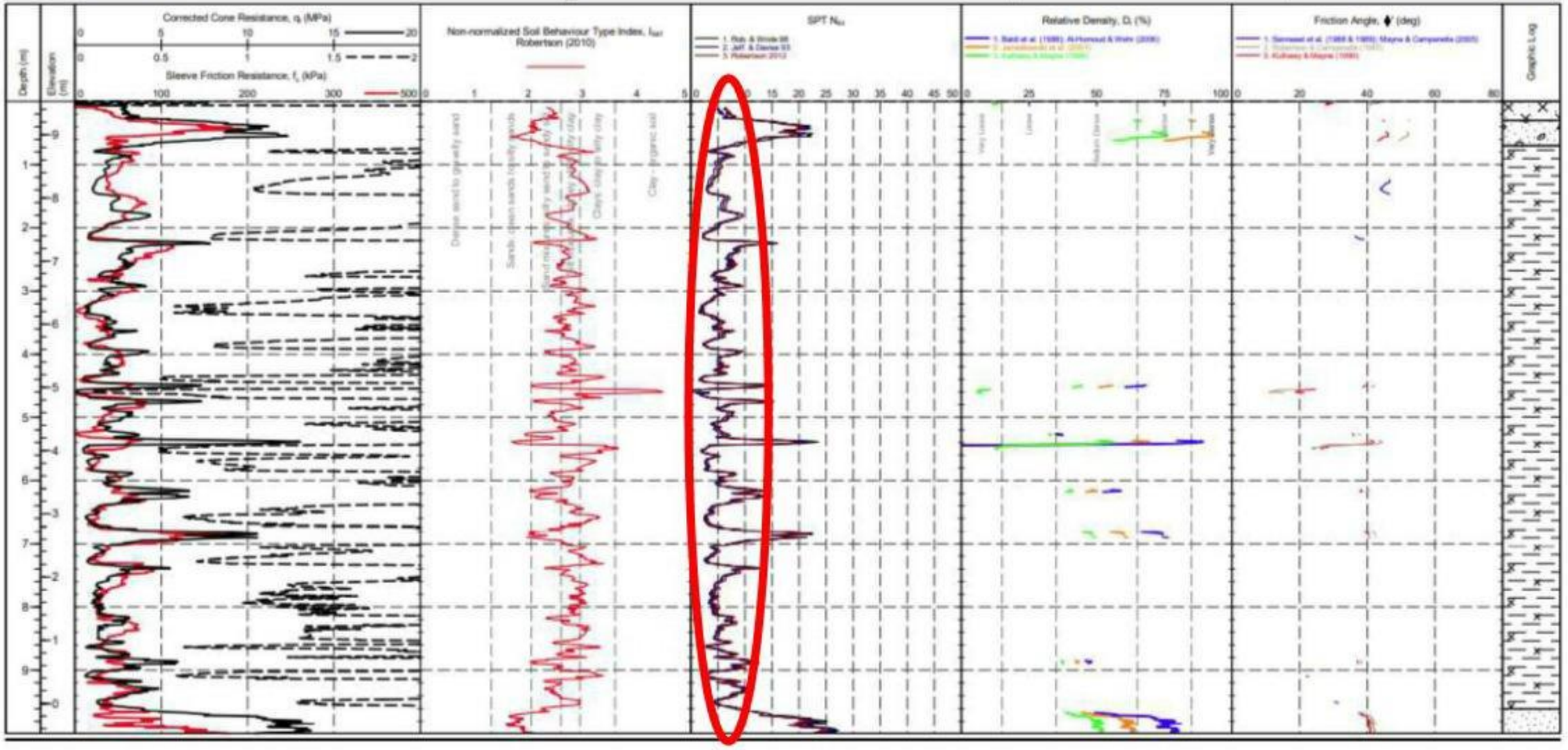
CLIENT : Delta Simons	EASTING : 470029.3 m	Remark:	SHEET : 2 OF 4
PROJECT : Brockhampton	NORTHING : 105595.0 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 10.20 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT113

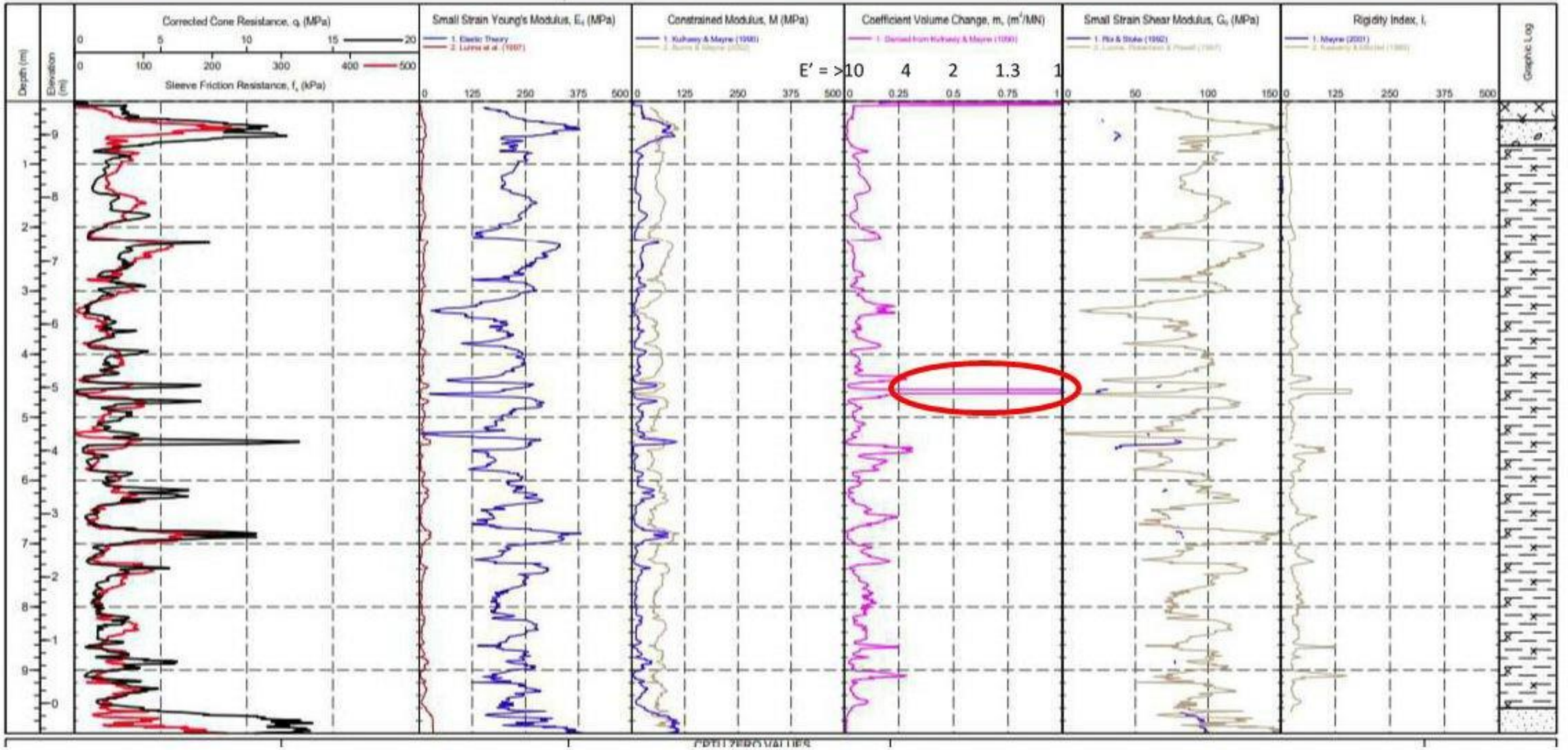
CLIENT : Delta Simons	EASTING : 470150.7 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105631.8 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 9.53 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



IN SITU
SITE INVESTIGATION Working with: deltasimons

PointID
CPT113

CLIENT : Delta Simons	EASTING : 470150.7 m	Remark:	SHEET : 1 OF 4
PROJECT : Brockhampton	NORTHING : 105631.8 m	Test refused on total pressure.	STATUS : Final
LOCATION : Brockhampton	ELEVATION : 9.53 m OD		TEST DATE : 29/03/2021
PROJECT No. : 1210220	CHECKED BY : LD		PLOT DATE : 25/05/2021
	TERMINATION REASON : Refusal		METHOD : ISO 22476-1:2012



Appendix D – Geotechnical Risk Register

Geotechnical Risk Register

The Geotechnical Risk Register has been compiled to show the degree of risk attached to various ground related aspects of the proposed development. The purpose of the register is to provide an assessment of the risk to the project posed by common ground related problems and identify suitable mitigation measures that control the risk to an acceptable level. The risk register should be developed and refined as the geotechnical design and assessment progresses such that the register will allow the management of the geotechnical risks.

The Geotechnical Risk Register has been developed in general accordance with the guidance presented in ICE/DETR Document 'Managing Geotechnical Risk' (2001) and the HE documents CS641 and CD622. The degree of risk (R) is determined by combining an assessment of the probability (P) of the hazard occurring with an assessment of the Impact (I) the hazard and associated mitigation will cause if it occurs (R = P x I). The scale against which the probability and impact are measure and the resulting degree of risk determined is presented below.

The inclusion of a risk in the register does not constitute confirmation that the problem actually exists at the Site. A probability of 'very unlikely' is indicative of a condition which the available data suggests should not be present. The calculated risk is not the risk that the impact will occur, it is the risk that the mitigation will be required to enable the project to progress. For the purposes of this risk register the magnitude of each impact and the resulting severity of risk is measured against that which would/could 'normally' be expected for each element. Before incorporation into a project risk register the impacts and risks for each element should be moderated by an assessment of the cost and time implication of individual mitigation measures.

Probability	**(P)**
Very Likely (VLk)	5
Likely (Lk)	4
Plausible (P)	3
Unlikely (U)	2
Very Unlikely (VU)	1

X

Impact	**(I)**
Very High (VH)	5
High (H)	4
Medium (M)	3
Low (L)	2
Very Low (VL)	1

=

(R)	**Risk**
20 – 25	Severe
15 – 19	Substantial
10 – 14	Moderate
5 – 9	Minor
1 – 4	Negligible

	Site Features / Ground Conditions	Hazard	Potential Impact	Before Control			Comments and Potential Mitigation
				Probability of Hazard	Magnitude of impact	Risk	
Slopes and Earthworks	Existing steep slopes surrounding the Site boundary & proposed bunds.	Slope failure	Surface deformation Structural damage Damage to services Health & Safety Risk to the public	4	4	16	Landscaped bunds are proposed along the western and southern boundaries of the Site, and an engineered slope is proposed for the eastern boundary adjacent to the off-Site canal. Existing slopes should be inspected for signs of instability prior to works being undertaken. The material proposed for use in the bunds is likely to be geotechnically suitable for re-use. For proposed 1 in 2 slopes it is recommended that a detailed slope stability analysis is undertaken. Based on the derived drained angle of shearing resistance stability may be marginal.
	Varying Site levels corresponding with heterogeneous soils and material	Requirement for cut / fill to accommodate proposal	Unsuitable formations and unstable earthworks due to underlying landfill waste. Possible soil condition degradation due to working practices.	4	3	12	The ground model at the Site comprises a cover layer comprising predominantly of cohesive soils with granular lenses becoming increasingly prevalent in the eastern landfill cell. Highly compressible landfill material at formation levels requires consideration in an earthwork's specification. Excessive settlement is likely to occur upon loading the ground and therefore ground improvement is recommended in external areas and potentially below proposed landscape bunds to mitigate against unacceptable levels of settlement.
Foundations & Substructures	Highly compressible Made Ground soils including landfill cover system and landfill material.	Ground unsuitable for conventional shallow footings and load bearing.	Low bearing capacity and excessive rates and volumes of settlement across areas of hardstanding.	4	4	16	The ground model at the Site comprises compressible landfill waste to depth. The assessment has demonstrated that settlement of the two landfill cells is likely to continue and accelerate in the event a surcharge load is applied to untreated Made Ground soils. In addition, CPT investigation has proven a lack of consolidation of landfill material with increasing depth. As such, a ground improvement program is recommended for areas of hardstanding in order to improve the geotechnical properties of the waste mass, and limit total and differential settlement. It is understood that the two proposed units are to be piled. Consideration must be given to settlement of external areas, in relation to the finished floor level of the proposed structures.

deltasimons

	Site Features / Ground Conditions	Hazard	Potential Impact	Before Control			Comments and Potential Mitigation
				Probability of Hazard	Magnitude of impact	Risk	
	Trees / hedgerows surrounding the Site perimeter	Risk of shrinking / swelling clay	Damage to foundations, hardstanding and services	3	3	9	Volume change potential should be considered where cohesive soils are present at shallow depths.
	Aggressive ground chemistry	Attack on buried concrete	Adverse impact on foundation integrity and strength	4	4	16	The two landfill cells comprise of assorted heterogeneous materials with the potential for contaminant accumulation within the cell mass. As such, elevated levels of sulphates and aggressive ground contaminants have been identified from relevant testing. Soil samples tested in accordance with BRE SD1 has determined the required classification of buried concrete to be Design Sulphate Class DS-3 and ACEC Class AC-3.
Floor slabs and road pavements	Soft, heterogeneous and compressible near-surface soil	Ground in its current form unsuitable for conventional ground bearing slab	Alternative floor design required	4	4	16	Ground bearing floor slabs are unsuitable for the Site assuming the shallow ground model in its current form. Following the finalisation of the cut and fill operation, it is likely that both units may span areas of cut and fill. Where floor slabs are proposed in areas of fill, providing soils are placed to an engineered specification, a ground bearing solution may be feasible. Ground improvement maybe required in the event a specification is insufficient for the required slab performance and tolerances. In areas of cut, where a new formation level is exposed, ground improvement will likely be required to stabilise and improve soils underlying the slab footprint.
		Very low CBR due to soft formation	Surface damage or alternative design				The ground model in its current form is unlikely to produce a stable and feasible CBR value for the design of access roads and hardstanding. In addition, a cut and fill is proposed for the Site. Following the finalisation of earthworks and ground improvement of external areas, in-situ Plate CBR testing is recommended in order to inform design.

deltasimons

	Site Features / Ground Conditions	Hazard	Potential Impact	Before Control			Comments and Potential Mitigation
				Probability of Hazard	Magnitude of impact	Risk	
Temporary Works & Construction Issues	Loose strata at shallow depth associated with landfill material High tidally influenced groundwater table, and perched groundwater bodies	Unstable excavations	Potential risk to the health and safety of construction works during development.	3	5	15	Unstable landfill material has been identified at relatively shallow depths within trial pit locations during the site investigation. Shallow excavations undertaken in areas of cut will likely encounter the landfill mass material sooner given the reduction in levels. Care must be taken in order to improve the stability of shallow excavations. The mitigating methodology for this may comprise of temporary shoring, ensuring the excavation is dewatered and the correct PPE is used throughout works.
	Obstructions within landfill material mass during piling operations.	Aborted piles and poor pile performance outside of acceptable parameters	Delays and additional construction costs	4	5	20	Due to the heterogeneity of the landfill mass, there is the risk of large obstructions being present within buried landfill material. There is therefore the potential, given the nature of driven piles, for aborted piles or poor driving conditions to arise during the construction of the two units. Potential mitigation measures such as pile probing maybe warranted in order to prove the viability of pile locations prior to commencing and installing driven piles. Delays associated with aborted pile etc. are likely to have a significant impact on project costs and programme.
	High tidally influenced groundwater table, and perched groundwater bodies	Unstable excavations	Consideration required during pile design	3	3	9	Due to the fluctuating groundwater table, and the presence of a perched groundwater body within the landfill cells, consideration should be given to this issue when considering pile design, particularly in the context of negative skin friction in landfill cells.

deltasimons

Appendix E – Groundwater Chemical Analysis Summary Table

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
Metals and Metalloids												
Chromium	86	16	7.21	WFD 2015c	21	RO101	12	8.1	NR	9.7	Landfill Waste	North-West
						RO102	16	NR	NR	NR		Centre
						RO103	12	10	NR	8.2		Central-West
						RO104	NR	7.6	NR	11		North-East
						RO105	14	11	NR	9		North-East
						RO106	14	<GAC	NR	14		Central-East
						CP02A	12	11	<GAC	NR		South-West
						CP03	13	10	<GAC	10		North-East
						CP05	15	NR	NR	10		Central-South
		19.9			9	DS101	12	<GAC	8	9.3	River Terrace Deposits	South-East
						DS102	13	<GAC	8.8	13		East
						DS103	19.9	7.6	<GAC	11		North-East
		16			5	RO101	16	<GAC	<GAC	<GAC	Chalk	North-West
						RO102	<GAC	7.6	<GAC	<GAC		Centre
						RO104	<GAC	10	<GAC	<GAC		Central-West
						RO105	<GAC	9.6	<GAC	<GAC		North-East
						CP02A	<GAC	NR	<GAC	9.9		South-West
Copper	86	37	2.12	WFD 2015c	21	RO101	6.1	8.1	NR	37	Landfill Waste	North-West
						RO102	7.1	NR	NR	NR		Centre
						RO103	5.6	8.3	NR	18		Central-West
						RO104	NR	13	NR	23		North-East
						RO105	<GAC	8.5	NR	8.5		North-East
						RO106	2.7	13	NR	11		Central-East
						CP02A	2.4	5.6	6.3	NR		South-West
						CP03	<GAC	3.0	3.3	8.9		North-East
						CP05	<GAC	NR	NR	9.9		Central-South
						CP02	4.0				Landfill Waste	South-West

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
						CP04	5.0					Central-West
		30			10	DS101	<GAC	4.6	8.7	5.1	River Terrace Deposits	South-East
						DS102	7	8.9	8.4	30		East
						DS103	3.6	<GAC	3.9	11		North-East
		17			36	RO101	9.1	14	9.8	17	Chalk	North-West
						RO102	5.8	7.9	4.4	8.4		Centre
						RO103	<GAC	12	<GAC	5.7		Central-West
						RO104	2.3	11	<GAC	2.7		North-East
						RO105	3.4	9.4	<GAC	2.8		North-East
						RO106	3.2	4.3	2.7	5.4		Central-East
						RO107	9.7	16	15	15		West
						RO108	7	6.1	6.4	4.4		Central-South
						RO109	4.4	5.1	5.4	4.3		South-East
						CP02A	NR	NR	11	16		South-West
						CP05	NR	9	6	NR		Central-South
Lead	86	19	2.54	WFD 2015c	1	RO104	19	<GAC	<GAC	<GAC	Chalk	North-East
Mercury	86	0.19	0.106	WFD 2015c	1	DS103	0.19	<GAC	<GAC	<GAC	River Terrace Deposit	North-East
		0.87			4	RO107	0.56	0.83	0.87	0.58	Chalk	West
Nickel	86	52	8.48	WFD 2015c	18	RO101	15	<GAC	NR	11	Landfill Waste	North-West
						RO102	52	NR	NR	NR		Centre
						RO103	9.2	11	NR	13		Central-West
						RO104	NR	9.1	NR	25		North-East
						RO105	<GAC	<GAC	NR	10		North-East
						RO106	10	<GAC	NR	12		Central-East
						CP02A	16	11	13	NR		South-West
						CP05	29	NR	NR	20		Central-South

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
						CP01	10.7				Landfill Waste	Centre
						CP04	9.3					Central-West
		130			13	DS101	15	23	33	27	River Terrace Deposits	South-East
						DS102	130	<GAC	19	20		East
						DS103	37	17	13	20		North-East
		60			27	RO101	60	<GAC	9.8	<GAC	Chalk	North-West
						RO102	9.2	23	19	43		Centre
						RO104	<GAC	8.7	<GAC	<GAC		North-East
						RO105	34	19	10	14		North-East
						RO106	20	40	35	28		Central-East
						RO107	20	24	19	15		West
						RO108	20	24	13	<GAC		Central-South
						RO109	29	14	12	10		South-East
						CP02A	NR	NR	<GAC	17		South-West
Zinc	86	38	23.1	WFD 2015c	3	RO103	<GAC	<GAC	NR	38	Waste	Central-West
						RO105	<GAC	<GAC	NR	26		North-East
						RO106	<GAC	<GAC	NR	35		Central-East
		540			7	RO102	<GAC	190	230	43	Chalk	Centre
						RO103	<GAC	<GAC	<GAC	<GAC		Central-West
						RO104	34	<GAC	<GAC	<GAC		North-East
						RO105	41	<GAC	<GAC	<GAC		North-East
						RO106	540	<GAC	<GAC	<GAC		Central-East
						CP05	NR	<GAC	27	NR		Central-South
Inorganics												
Ammoniacal Nitrogen as NH3*	85	405.5	300	WFD 2015d	3	RO104	NR	317.6	NR	<GAC	Landfill Waste	North-East
						RO106	308.5	<GAC	NR	405.5		Central-East
		377.5			1	DS102	377.5	<GAC	<GAC	<GAC	River Terrace Deposits	East

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
Ammoniacal Nitrogen as NH4**	85	535,990	500	DWQS 2016	30	RO101	38,000	39,000	NR	89,000	Waste	North-West
						RO102	250,000	NR	NR	NR		Centre
						RO103	46,000	110,000	NR	120,000		Central-West
						RO104	NR	180,000	NR	190,000		North-East
						RO105	78,000	65,000	NR	74,000		North-East
						RO106	220,000	180,000	NR	230,000		Central-East
						CP02A	45,000	46,000	66,000	NR		South-West
						CP03	26,000	26,000	20,000	23,000		North-East
						CP05	55,000	NR	NR	100,000		Central-South
						CP01	535,990				Waste	Centre
						CP02	170,930					South-West
						CP03	16,720					North-East
						CP04	197,860					Central-West
						CP05	123,570					Central-South
						CP06	111,360					South-East
		190,000			12	DS101	87,000	85,000	63,000	86,000	River Terrace Deposits	South-East
						DS102	170,000	150,000	150,000	190,000		East
						DS103	76,000	130,000	110,000	140,000		North-East
		140,000			26	RO101	140,000	73,000	88,000	81,000	Chalk	North-West
						RO102	3,400	33,000	14,000	41,000		Centre
						RO103	<GAC	<GAC	<GAC	<GAC		Central-West
						RO104	<GAC	<GAC	<GAC	<GAC		North-East
						RO105	28,000	44,000	26,000	25,000		North-East
						RO106	17,000	23,000	13,000	12,000		Central-East
						RO107	<GAC	<GAC	<GAC	<GAC		West
						RO108	47,000	43,000	17,000	3,500		Central-South
						RO109	25,000	19,000	14,000	10,000		South-East
						CP02A	NR	NR	66,000	95,000		South-West

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
						CP01	3,310				Chalk	Centre
						CP02	106,130					South-West
						CP03	2,290					North-East
Nitrate as NO3	85	1,300,000	37,500	WFD 2015c	1	DS103	<GAC	1,300,000	<GAC	<GAC	River Terrace Deposits	North-East
Nitrite as NO2	85	4,500	500	DWQS 2016	7	RO102	3,320	<GAC	<GAC	5,300	Chalk	Centre
						RO105	4,500	<GAC	<GAC	<GAC		North-East
						RO108	<GAC	<GAC	<GAC	770		Central-South
						RO109	510	<GAC	630	1,100		South-East
Chloride	85	840,000	188,000	WFD 2015c	16	RO101	250,000	320,000	NR	330,000	Waste	North-West
						RO102	560,000	NR	NR	NR		Centre
						RO103	340,000	840,000	NR	750,000		Central-West
						RO104	NR	420,000	NR	410,000		North-East
						RO105	<GAC	200,000	NR	<GAC		North-East
						RO106	510,000	500,000	NR	630,000		Central-East
						CP02A	NR	580,000	570,000	NR		South-West
						CP05	<GAC	NR	NR	230,000		Central-South
		350,000,000			12	DS101	340,000	480,000	460,000	510,000	River Terrace Deposits	South-East
						DS102	2,100,000	2,900,000	2,600,000	1,900,000		East
						DS103	460,000	350,000,000	330,000	430,000		North-East
		2,300,300			21	RO101	450,000	630,000	770,000	1,000,000	Chalk	North-West
						RO102	280,000	310,000	<GAC	200,000		Centre
						RO106	420,000	540,000	480,000	490,000		Central-East
						RO107	1,300,000	2,300,000	1,200,000	930,000		West
						RO108	410,000	370,000	330,000	270,000		Central-South
						CP02A	NR	NR	650,000	810,000		South-West
Polyaromatic Hydrocarbons												
Naphthalene	86	33.7	4.24		8	RO101	9.74	10.2	NR	5.11	Landfill Waste	North-West

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
				WFD 2015e		RO103	<GAC	<GAC	NR	4.26		Central-West
						RO106	5.9	<GAC	NR	<GAC		Central-East
						CP01	33.7				Landfill Waste	Centre
						CP04	7.1					Central-East
						CP06	7.1					South-West
		14.8			1	DS101	14.8	<GAC	<GAC	<GAC	River Terrace Deposits	South-East
Anthracene	86	0.69	0.1936	WFD 2015e	6	RO101	0.21	<GAC	NR	<GAC	Landfill Waste	North-West
						RO102	0.23	NR	NR	NR		Centre
						RO106	0.69	0.29	NR	<GAC		Central-East
						CP01	0.27				Landfill Waste	Centre
						CP04	0.23					Central-East
		0.45			2	DS101	0.45	<GAC	<GAC	<GAC	River Terrace Deposits	South-East
						DS103	<GAC	0.23	<GAC	<GAC		North-East
		0.21			1	CP02	0.21				Chalk	South-West
Fluoranthene	86	1.34	0.12	WFD 2015a	7	RO101	0.36	<GAC	NR	<GAC	Landfill Waste	North-West
						RO102	0.32	NR	NR	NR		Centre
						RO103	0.75	<GAC	NR	<GAC		Central-West
						RO106	1.34	<GAC	NR	<GAC		Central-East
						CP01	0.52				Landfill Waste	Centre
						CP02	0.25					South-West
						CP04	0.21					Central-East
		1.74			2	DS101	1.74	<GAC	<GAC	<GAC	River Terrace Deposits	South-East
						DS103	<GAC	0.33	<GAC	<GAC		North-East
		0.29			2	RO106	0.29	<GAC	<GAC	<GAC	Chalk	Central-East
						CP02	0.22				Chalk	South-West
Benzo[b]fluoranthene	86	0.28	0.058	WFD 2015e	1	RO106	0.28	<GAC	NR	<GAC	Waste	Central-East

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
Benzo[a]pyrene	86	0.49	0.27	WFD 2015a	1	RO106	0.47	<GAC	NR	<GAC	Waste	Central-East
Petroleum Hydrocarbons												
Benzene	86	10.5	10	WFD 2015a	1	RO101	<GAC	<GAC	NR	10.5	Landfill Waste	North-West
Ethylbenzene	86	30.5	20	EQS	2	RO103	24.6	<GAC	NR	30.5	Landfill Waste	Central-West
Aromatic TPH >C5-C7	86	11	10	WFD 2015a	1	RO101	<GAC	<GAC	NR	11	Landfill Waste	North-West
Aromatic TPH >C8-C10	86	140	20	EQS	5	RO101	33	<GAC	NR	<GAC	Landfill Waste	North-West
						RO103	110	70	NR	140		Central-West
						CP04	24				Landfill Waste	Central-East
Total Petroleum Hydrocarbons [#]	86	2,423	300	WHO	18	RO101	1,218	1,271	NR	2,331	Waste	North-West
						RO102	1,723	NR	NR	NR		Centre
						RO103	1,695	1,806	NR	928		Central-West
						RO104	NR	1,870	NR	370		North-East
						RO105	750	970	NR	<GAC		North-East
						RO106	2,423	563	NR	670		Central-East
						CP02A	<GAC	705	<GAC	660		South-West
						CP05	540	NR	NR	350		Central-South
		1,180			8	DS101	810	1,180	<GAC	<GAC	River Terrace Deposits	South-East
						DS102	1,120	1,650	<GAC	460		East
						DS103	520	950	<GAC	440		North-East
		3,360			7	RO101	1,278	3,360	<GAC	360	Chalk	North-West
						RO102	<GAC	392	<GAC	<GAC		Centre
						RO104	960	<GAC	<GAC	<GAC		North-East
						RO106	<GAC	1,120	<GAC	<GAC		Central-East
						CP05	NR	1,380	<GAC	NR		Central-South
Organics												
Total Phenols	19	63	7.7		1	RO101	63	<GAC	NR	NR	Landfill Waste	North-West

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances - Concentration (µg/l)					Strata	Area of Site of Exceedance
						Borehole	Round 1	Round 2	Round 3	Round 4		
		11		WFD 2015b	1	DS103	<GAC	11	NR	NR	River Terrace Deposits	North-East
		12			1	RO102	<GAC	12	NR	NR	Chalk	Centre

Notes: DWQS 2016 = The Water Supply (Water Quality) Regulations 2016 [UK Drinking Water Standards]

#TPH - The WHO guidance states that the use of the lowest guidance value for aliphatic hydrocarbons (300 ug/l) to the total TPH concentration in groundwater will provide a conservative level of protection.

WFD 2015a - Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. Part 3 Table 1 - EQS for Priority Substances and Other Pollutants used to clarify chemical status

WFD 2015b - Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. Part 2 Table 1 - Standards for Specific Pollutants

WFD 2015c - Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. Schedule 5 Table 1 - Threshold Values for Groundwater

WFD 2015d - Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. Schedule 3 Physiochemical Standards (Good standard)

*Calculated by Delta-Simons with temperate and pH values included

**Calculated by the laboratory (Ammoniacal Nitrogen multiplied by (18/14))

CPXX = WYG Data

NR = Sample not collected (i.e. due to dry well / inaccessible)

<GAC = Concentration below the GAC

= Total sum of all aliphatic and aromatic hydrocarbons

Landfill Waste

River Terrace Deposits

Chalk

Appendix F – Ammoniacal Nitrogen Data Summary

		Borehole	Ammoniacal Nitrogen as NH3	pH	Ammoniacal Nitrogen Total	N as mg/l	Unionised Ammonia Concentration (mg/l) (numbers input into calculator)	Percentage of NH3
Waste	Round 1	RO101	38000	6.8	31160	31.16	0.042	0.14
		RO102	250000	6.8	205000	205	0.279	0.14
		RO103	46000	6.7	37720	37.72	0.041	0.11
		RO105	78000	6.8	63960	63.96	0.087	0.14
		RO106	220000	6.9	180400	180.4	0.309	0.17
		CP02A	45000	6.9	36900	36.9	0.063	0.17
		CP03	26000	6.8	21320	21.32	0.029	0.14
		CP05	55000	6.7	45100	45.1	0.049	0.11
	Round 2	RO101 (S)	39000	6.9	31980	31.98	0.055	0.17
		RO103 (S)	110000	6.8	90200	90.2	0.123	0.14
		RO104 (S)	180000	7	147600	147.6	0.318	0.22
		RO105 (S)	65000	6.9	53300	53.3	0.091	0.17
		RO106 (S)	180000	6.9	147600	147.6	0.252	0.17
		CP02A (S)	46000	7	37720	37.72	0.081	0.22
		CP03 (S)	26000	6.7	21320	21.32	0.023	0.11
	Round 3	CP02A (S)	66000	6.9	54120	54.12	0.093	0.17
		CP03 (S)	20000	6.8	16400	16.4	0.022	0.14
	Round 4	RO101 S	89000	6.8	72980	72.98	0.099	0.14
		RO101 D	81000	6.8	66420	66.42	0.090	0.14
		RO103 S	120000	6.9	98400	98.4	0.168	0.17
		RO104 S	190000	6.9	155800	155.8	0.266	0.17
		RO105 S	74000	7	60680	60.68	0.131	0.22
		RO106 S	230000	7	188600	188.6	0.405	0.21
		CP03 S	23000	6.8	18860	18.86	0.026	0.14
		CP05	100000	6.9	82000	82	0.140	0.17

RTD	Round 1	DS101	87000	7	71340	71.34	0.154	0.22
		DS102	170000	7.1	139400	139.4	0.377	0.27
		DS103	76000	7.1	62320	62.32	0.169	0.27
	Round 2	DS101	85000	6.9	69700	69.7	0.119	0.17
		DS102	150000	6.8	123000	123	0.167	0.14
		DS103	130000	6.9	106600	106.6	0.182	0.17
	Round 3	DS101	63000	6.9	51660	51.66	0.088	0.17
		DS102	150000	6.8	123000	123	0.167	0.14
		DS103	110000	6.9	90200	90.2	0.154	0.17
	Round 4	DS101	86000	6.9	70520	70.52	0.121	0.17
		DS102	190000	6.8	155800	155.8	0.212	0.14
		DS103	140000	6.8	114800	114.8	0.156	0.14
Chalk	Round 1	RO101	140000	6.9	114800	114.8	0.196	0.17
		RO102	3400	7	2788	2.788	0.006	0.22
		RO103	15	7.2	12.3	0.0123	0.000	0.34
		RO104	140	7.4	114.8	0.1148	0.001	0.54
		RO105	28000	7	22960	22.96	0.049	0.22
		RO106	17000	7.2	13940	13.94	0.047	0.34
		RO107	230	7.2	188.6	0.1886	0.001	0.34
		RO108	47000	7	38540	38.54	0.083	0.22
		RO109	25000	7	20500	20.5	0.044	0.22
	Round 2	RO101 (D)	73000	6.9	59860	59.86	0.102	0.17
		RO102 (D)	33000	6.8	27060	27.06	0.037	0.14
		RO103 (D)	120	7.3	98.4	0.0984	0.000	0.43
		RO104 (D)	44	7.3	36.08	0.03608	0.000	0.43
		RO105 (D)	44000	6.9	36080	36.08	0.062	0.17
		RO106 (D)	23000	7.1	18860	18.86	0.051	0.27
		RO107	120	7.3	98.4	0.0984	0.000	0.43
		RO108	43000	7	35260	35.26	0.076	0.22

		RO109	19000	7	15580	15.58	0.034	0.22
	Round 3	RO101 (D)	88000	6.8	72160	72.16	0.098	0.14
		RO102 (D)	14000	6.9	11480	11.48	0.020	0.17
		RO103 (D)	26	7.3	21.32	0.02132	0.000	0.43
		RO104 (D)	120	7.2	98.4	0.0984	0.000	0.34
		RO105 (D)	26000	7	21320	21.32	0.046	0.22
		RO106 (D)	13000	7	10660	10.66	0.023	0.22
		RO107 (D)	40	7.2	32.8	0.0328	0.000	0.34
		RO108	17000	7.1	13940	13.94	0.038	0.27
		RO109	14000	7.1	11480	11.48	0.031	0.27
		CP02A (D)	66000	6.9	54120	54.12	0.093	0.17
	Round 4	RO101 D	81000	6.8	66420	66.42	0.090	0.14
		RO102 D	41000	7	33620	33.62	0.072	0.22
		RO103 D	100	7.4	82	0.082	0.000	0.54
		RO104 D	85	7.4	69.7	0.0697	0.000	0.54
		RO105 D	25000	7	20500	20.5	0.044	0.22
		RO106 D	12000	7	9840	9.84	0.021	0.22
		RO107	110	7.3	90.2	0.0902	0.000	0.43
		RO108	3500	7.2	2870	2.87	0.010	0.34
		RO109	10000	7.1	8200	8.2	0.022	0.27
		CP02A D	95000	6.8	77900	77.9	0.106	0.14
Stream	Round 1	Upstream High Tide	24	7.4	19.68	0.01968	0.000	0.54
		Midstream High Tide	< 15	7.5	-	-	-	-
		Downstream High Tide	17	7.5	13.94	0.01394	0.000	0.68
		Upstream Low Tide	15	7.7	12.3	0.0123	0.000	1.07
		Midstream Low Tide	130	7.7	106.6	0.1066	0.001	1.07
		Downstream Low Tide	92	7.8	75.44	0.07544	0.001	1.34
	Round 2	Upstream High Tide	48	7.7	39.36	0.03936	0.000	1.06
		Midstream High Tide	31	7.7	25.42	0.02542	0.000	1.05

		Downstream High Tide	18	7.7	14.76	0.01476	0.000	1.07
		Upstream Low Tide	15	7.8	12.3	0.0123	0.000	1.34
		Midstream Low Tide	100	7.9	82	0.082	0.001	1.68
		Downstream Low Tide	87	7.9	71.34	0.07134	0.001	1.68

Appendix G – HR Wallingford IH124 Calculations Sheet – Total Site Area

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Joshua Rigby
Site name:	Brockhampton Landfill Site
Site location:	Broadmarsh Business Centre, Harts Farm Way, Havant PO9 1HS

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	50.84645° N
Longitude:	1.00462° W
Reference:	2243513253
Date:	Jun 11 2021 13:53

Runoff estimation approach IH124

Site characteristics

Total site area (ha): 8.357

Methodology

Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	3	3
HOST class:	N/A	N/A
SPR/SPRHOST:	0.37	0.37

Hydrological characteristics

	Default	Edited
SAAR (mm):	720	720
Hydrological region:	7	7
Growth curve factor 1 year:	0.85	0.85
Growth curve factor 30 years:	2.3	2.3
Growth curve factor 100 years:	3.19	3.19
Growth curve factor 200 years:	3.74	3.74

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	24.81	24.81
1 in 1 year (l/s):	21.09	21.09
1 in 30 years (l/s):	57.07	57.07
1 in 100 year (l/s):	79.15	79.15
1 in 200 years (l/s):	92.8	92.8

This report was produced using the greenfield runoff tool developed by HR Wallingford and available at www.uksuds.com. The use of this tool is subject to the UK SuDS terms and conditions and licence agreement , which can both be found at www.uksuds.com/terms-and-conditions.htm. The outputs from this tool are estimates of greenfield runoff rates. The use of these results is the responsibility of the users of this tool. No liability will be accepted by HR Wallingford, the Environment Agency, CEH, Hydrosolutions or any other organisation for the use of this data in the design or operational characteristics of any drainage scheme.

Appendix H – HR Wallingford IH124 Calculations Sheet – Proposed Development

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Joshua Rigby
Site name:	Brockhampton Landfill Site
Site location:	Broadmarsh Business Centre, Harts Farm Way, Havant PO9 1HS

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	50.84645° N
Longitude:	1.00462° W
Reference:	3523533047
Date:	Jun 11 2021 13:55

Runoff estimation approach IH124

Site characteristics

Total site area (ha): 3.243

Methodology

Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	3	3
HOST class:	N/A	N/A
SPR/SPRHOST:	0.37	0.37

Hydrological characteristics

	Default	Edited
SAAR (mm):	720	720
Hydrological region:	7	7
Growth curve factor 1 year:	0.85	0.85
Growth curve factor 30 years:	2.3	2.3
Growth curve factor 100 years:	3.19	3.19
Growth curve factor 200 years:	3.74	3.74

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	9.63	9.63
1 in 1 year (l/s):	8.18	8.18
1 in 30 years (l/s):	22.15	22.15
1 in 100 year (l/s):	30.72	30.72
1 in 200 years (l/s):	36.01	36.01

This report was produced using the greenfield runoff tool developed by HR Wallingford and available at www.uksuds.com. The use of this tool is subject to the UK SuDS terms and conditions and licence agreement , which can both be found at www.uksuds.com/terms-and-conditions.htm. The outputs from this tool are estimates of greenfield runoff rates. The use of these results is the responsibility of the users of this tool. No liability will be accepted by HR Wallingford, the Environment Agency, CEH, Hydrosolutions or any other organisation for the use of this data in the design or operational characteristics of any drainage scheme.