



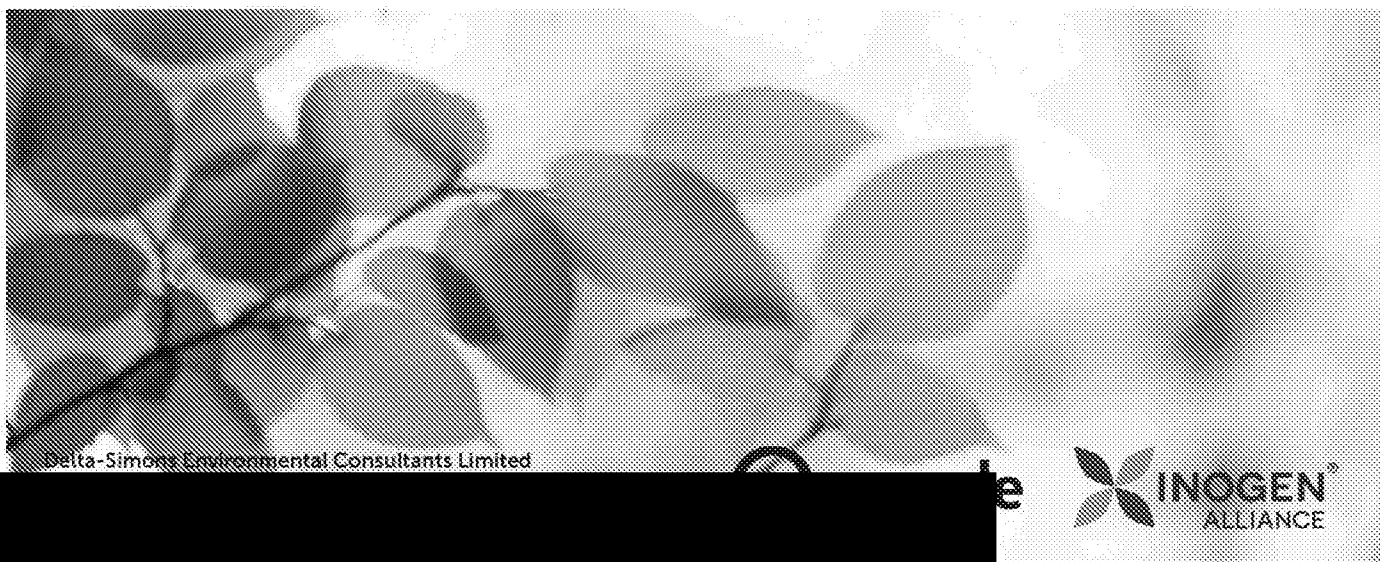
Geo-Environmental Assessment

Oldlands Farm, Bognor Regis

Presented to Lysander Associates

Issued: September 2021

Delta-Simons Project No. 20-1543.07



Delta-Simons Environmental Consultants Limited



Report Details

Client	Lysander Associates
Report Title	Geo-Environmental Assessment
Site Address	Oldlands Farm, Newlands Road, Bognor Regis, PO22 9NN
Project No.	20-1543.07
Report Date	September 2021
Delta-Simons Contact	David Josling [REDACTED]

Quality Assurance

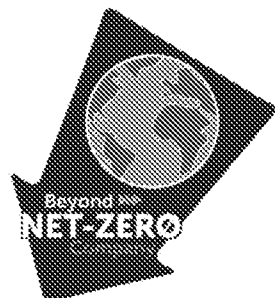
Issue No.	Status	Issue Date	Comments	Author	Technical Review	Authorised
3	Final	7 th September 2021	Updated to remove references to the Development Drawing.	[REDACTED]		
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Executive Summary

Brief	Delta-Simons Environmental Consultants Limited ("Delta-Simons") was instructed by Lysander Associates (the "Client") to prepare a Geo-Environmental Assessment for Oldlands Farm, Newlands Road, Bognor Regis PO22 9NN (the "Site") The purpose of this assessment is to provide a suitable geo-environmental assessment and identify the potential for geotechnical issues to be present at the Site in the context of the proposed development.
Site Setting	The Site is located across two parcels of land in the northern outskirts of Bognor Regis, with the southern parcel to be used as the Main Development Area and the northern parcel to be used as a Flood Compensation Area. Both parcels of land have historically been used for agricultural purposes with minimal development on Site taking place associated with the construction of the A259 fly over.
Ground Conditions	The Site has undergone several phases of ground investigation, with ground conditions within the Main Development Area generally found to comprise a sequence of Topsoil to depths of 0.70 m bgl followed by Raised Marine Deposits comprising gravelly, sandy clay to depths of 6.0 m bgl which in turn was found to be underlain by the Undifferentiated Chalk Formation, to depths of >35 m bgl Ground conditions within the Flood Compensation Area, and Fill Extraction Area were found to comprise a sequence of Topsoil to depths of 0.50 m bgl followed by River Terrace deposits comprising gravelly silty clay to depths of 3.0 m bgl. A limited area of Made Ground was identified where traces of red brick were identified within the topsoil within the Flood Compensation Area. Deposits of the Undifferentiated Chalk Formation was found underlying the River Terrace Deposits and was comprised of structureless chalk. Groundwater levels have been monitored in the Raised Marine Deposits between 0.25 and 1.88m bgl (-0.05 – 0.71m AOD) and within the Undifferentiated Chalk between 0.51 and 1.89m bgl (-0.86 to 0.56m AOD)..and are likely to display seasonal variations. During ground investigations phases and reconnaissance during winter months, the ground has been noted to be saturated with large areas of standing water observed.
Land Contamination Assessment	<u>Human Health</u> None of the site-specific contaminants of concern were recorded at concentrations in excess of their respective assessment criteria. It is therefore considered that there is no significant risk of contamination to future site users or construction workers set in the context of a commercial end use <u>Controlled Waters</u> Widespread significant groundwater contamination has not been identified at the Site. Localised, elevated concentrations of sulphate, chloride, nickel and copper were identified within groundwater samples from the Raised Marine Deposits and Undifferentiated Chalk Formation. It is considered that they do not pose a significant risk to nearby surface waters considering that no sources of contamination has been identified on Site. It is equally likely that the recorded exceedances are representative of background conditions. and do not pose a significant risk to controlled waters. <u>Built Environment</u> Based on the findings of the ground investigations, soils within the Main Development Area and the Flood Compensation Area can be classified as DS-1 and ACEC Class AC-1 for soils and groundwater when considering the most appropriate type of concrete to be used at the Site.

	Ground Gas Ground gas monitoring indicates the Site can be classified as CS1. A final round of ground gas monitoring is remaining and on completion of the ground gas monitoring programme, this classification will be reassessed.
Geotechnical Assessment	The Raised Marine Deposits have been found to exhibit low shear strengths and are not considered a suitable founding stratum. Due to depths to competent Undifferentiated Chalk, shallow spread foundations are not considered suitable and a piled foundation solutions with a suspended floor slab is recommended. The Main Development Area is to be raised by 2m with materials extracted from the FCA/FEA. Based on initial calculations external areas are likely to be prone to settlements up to 50mm due to the imposition of the engineered fill therefore ground improvement techniques comprising surcharging or the use of vibro concrete columns may need to be adopted to minimise total settlements and enable the placement of engineered fill. Whilst surcharging may prove a more cost-effective solution, timeframes for the placement of the material may not permit the use of this technique especially during periods of inclement weather. The results of CBR tests have indicated generally very low CBR values 1-3% in the Main Development increasing to ~5% in the higher areas of the Main Development Area. It is therefore likely that significant protection and stabilisation of shallow soils will be required during the placement of engineered fill and also during road construction which may comprise the use of geotextile and separator membranes along with lime stabilisation to improve subgrade performance. The results of an earthworks classification exercise on materials within the FCA has indicated that the River Terrace Deposits are likely to be classified as Class 2A/2B whilst materials within the Undifferentiated Chalk are likely to be classed as Class 3. The testing has indicated that materials are generally suitable in their current condition for use as engineered fill however they are highly sensitive to moisture content variation and may be prone to deterioration when wet. Both materials are likely to be suitable for use during summer months however due to shallow groundwater water and inclement weather, the deeper chalk is likely to be prone to more rapid deterioration and it may not be possible to utilise or handle this material during these periods. It should also be noted that the River Terrace Deposits may also need the addition of significant lime in order to control moisture contents during inclement weather. General observations during winter periods combined with CBR results have indicated that the Site may be flooded/ saturated, and it may not be possible to safely undertake earthworks. Where conditions permit, it is likely that haulage roads using significant thicknesses of imported granular material placed on a geotextile membrane will be required to permit the movement and placement of materials across the Site. Buried concrete should be designed to resist DS1-AC1 chemically aggressive ground conditions.
Recommendations	Based on the findings of this report, the following recommendations are made: ⚡ Preparation of an Earthworks Specification for reuse of soils. ⚡ Earthworks undertaken across the Site may need to be completed under an appropriate Materials Management Plan (MMP). ⚡ It is recommended that specialist contractors confirm the suitability of the proposed foundation solutions, specifically the viability of vibro concrete piles to allow the rapid raising of site levels within Main Development Area. ⚡ Should earthworks be undertaken during the winter period then earthworks and upfilling activities may become flooded/ inaccessible and t require significant stabilisation and treatment of formation levels and materials to be placed as engineered fill;

	- Where time permits, it is recommended that seasonal groundwater monitoring is undertaken in areas to be subject to extraction activities to understand groundwater levels and establish availability of material for use as engineered fill. - Network Rail should be consulted at the earliest opportunity to consult on the effects of the land raising activities on the railway. - A 'hotspot' protocol should be in place during development works in case unanticipated contamination is encountered. (Appendix L).
This is intended as a summary only. Further detail and the limitations of the assessment are provided within the main body of the Report.	

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1.0 Introduction

1.1 Appointment

Delta-Simons Environmental Consultants Limited ("Delta-Simons") was instructed by Lysander Associates (the "Client") to prepare a Geo-Environmental Assessment for Oldlands Farm, Newlands Road, Bognor Regis PO22 9NN (the "Site"). Following the provision of the initial instruction, Delta Simons was subsequently instructed to assess an additional parcel of land to the north west which had been allocated for use as a Flood Compensation Area and as a source of material for upfilling the main development.

1.2 Context & Purpose

The main aim of the study was to provide information for geotechnical design parameters and to inform the suitability of materials won from the construction of the Flood Compensation Areas for use as engineered fill in relation to increasing levels within the main development.

As part of these works, additional soil and groundwater chemical analysis assessment has been undertaken to support any future material movements across the Site. 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 report provides recommendations for further work (where appropriate) based on the findings of the investigation.

It is understood that the southern section of the Site is to be developed for the erection of a warehouse (Use Class B8) with ancillary office, associated vehicle parking, multi storey van storage, plant, ancillary structures, lighting, landscaping and infrastructure works within the main development (southern parcel of land).

It is further understood that activities in the northern parcel of land will comprise the excavation of a Flood Compensation Area (FCA) with suitable engineered materials transferred to the main development area in order to raise Site levels. Due to the shallow groundwater table, it is likely that insufficient material will be available to adequately raise levels and further excavation beyond the FCA will be required to provide a net mass balance for the development scheme. The resulting excavation within the FCA will then be backfilled with site won topsoil reinstating this area back to its original surfacing.

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](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004408/NPPF_JULY_2021.pdf) web pages, the relevant requirements of the National Planning Policy Framework (NPPF) (as revised 2021) (paragraphs 174 & 183-184)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 March 2021 (ref.20-1543.07)

An addendum proposal was subsequently issued dated 13th April 2021 (ref 20-1543.07 v2) to support the investigation of the FCA and to assess the suitability of Site won materials for use as engineered fill.

The scope of works is outlined in Section 2.0.

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

¹

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004408/NPPF_JULY_2021.pdf

² <https://www.gov.uk/guidance/land-affected-by-contamination>

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 Existing Information

Delta Simons has previously issued the following reports in relation to the Site:

- ▲ Preliminary Geo-Environmental Risk Assessment, Bognor Regis, Oldlands Farm, Ref. 20-1543.04 v4 dated June 2021.

In addition, the following information has been made available to Delta-Simons for review and it is understood that reliance will be provided on this information.

- ▲ Hydrock – Phase 1a and 2 Oldlands Farm, Bognor Regis ref BOG-HYDGI-RP-GE1001-S2-P4, dated August 2018).

1.5 Limitations

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

- ▲ Foundation solutions have not been finalised for the Site.
- ▲ Travellers occupying the Site prevented the collection of gas and groundwater monitoring data on two occasions: and
- ▲ Saturated Moisture Content tests scheduled to be undertaken on geotechnical samples were unable to be carried out on chalk samples due to over saturation.

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 1.4 which should be consulted for further detail.

Co-ordinates	Centred approximately at National Grid Reference 494570, 101850	Elevation	<u>0 – 5.96m AOD</u>
		Area	<u>18.9 Ha</u>
Site Location	The Site is located in two parcels of land in the northern outskirts of Bognor Regis, approximately 3 km north-east from central Bognor Regis. The first parcel of land to be used for development is located to the south-east of the A259 road. The second parcel of land is indicated to be used as a flood compensation zone and it is proposed to excavate fill material from this area and transport it to the southern parcel of land to create a development platform. A Site location map is provided as Figure 1.		
Current Site Use	The Site and adjacent proposed flood compensation area (FCA) and flood extraction area (FEA) currently comprises undeveloped agricultural land with field boundaries and drains present crossing horizontally in an east-west direction. The Site is accessible from the A259, turning south-east onto an access road which grants entry to the Site.		
Proposed Development	It is understood that the development will comprise the erection of a warehouse (Use Class B8) with ancillary office, associated vehicle parking, van storage, plant, ancillary structures, lighting, landscaping, and infrastructure works in the southern parcel of land. Activities in the northern parcel of land will comprise the excavation of a Flood Compensation Area with suitable engineered materials transferred to the main development area in order to raise Site levels by approximately 2m. To achieve this, it is proposed to import 85,700m³ of material from the Flood Compensation Area. Due to the shallow groundwater table, it is likely that insufficient material will be available from the FCA to adequately raise levels and further excavation beyond the FCA will be required from a Fill Extraction Area (FEA) to provide a net mass balance for the development scheme. The resulting excavation within the FCA and FEA will then be backfilled with site won topsoil reinstating this area back to its original surfacing.		
Environmental Setting	From British Geological Survey mapping (1:50,000 Sheet Number 317/332, Chichester and Bognor), indicates the eastern half of the site to be underlain by superficial deposits of Raised Marine Deposits consisting of clay, silt, sand and gravel whereas to the west the superficial geology consists of River Terrace Deposits (undifferentiated) containing sand, silt, and clay. The underlying bedrock comprises undifferentiated chalks of the Lewis Nodular Chalk Formation, Seaford Chalk Formation, Newhaven Chalk Formation, Culver Chalk Formation and the Portsdown Chalk Formation. Ground conditions encountered during previous ground investigations by Hydrock and Delta-Simons within the main Site area have encountered the following generalised stratigraphy to be present: ▲ Topsoil comprising dark brown gravelly slightly clayey sand to depths between 0.2 and 0.80 m below ground level (bgl); ▲ Raised Marine Deposits comprising gravelly sandy clay to depths of 6.0 m bgl;		

	 Undifferentiated chalks comprising light grey to white gravelly silt, identified to depths of >35 m bgl. Ground conditions within the Flood Compensation Area and Fill Extraction Area, were found to comprise a sequence of;  Topsoil to depths of 0.50 m bgl;  River Terrace Deposits, comprising gravelly silty clay to depths of 3.0 m bgl; and  Undifferentiated Chalk deposits to depths greater than 3.0 m bgl. The bedrock geology of Undifferentiated Chalk Formation is classified as a Principal Aquifer, whilst groundwater within the superficial deposits of the Raised Marine Deposits and River Terrace Deposits are classified as a Secondary A Aquifer. Additionally, the Site is not located within groundwater Source Protection Zone / protected area. From the groundwater monitoring data contained within the previous Hydrock Ground investigation report in 2018 the groundwater table is standing at approximately 0.41 m to 1.51 m bgl. In addition to this, groundwater levels monitored by Delta-Simons during an earlier due diligence investigation monitored groundwater levels between 0.25 to 1.43 m bgl (0.71 to -0.06m AOD) within the Raised Marine Deposits and between 0.51 and 1.74 m bgl (0.48 -0.13m AOD) within the Undifferentiated Chalk Formation. Groundwater is expected to flow to the east, towards the Lidsey Rife River. There are no recorded groundwater abstractions within 1 km of the Site.
Key Historical Features	Historical sources dating back to 1876 show the Site and FCA to be utilised as agricultural land until present day with no previous development besides the earthworks which took place pre-2017. The surrounding area was also agricultural land up until 2012 when the A259 road began construction. By 2015 light industrial development had occurred at land south of the Site. Potential sources of on-site contamination could arise from agricultural sources including pesticides and herbicides. During the construction of the A259 land south west of the Site was used as a compound (2012-2015) creating potential on site sources of contamination. Potential historical sources of contamination included within historical mapping include:  Construction activities associated with the construction of the A259 to the west and north and the commercial units to the south; and  Industrial/ trading estate 300m to the south. However, the risks posed by these features were considered to be low in the context of the proposed development.
Summary of Previous Reports	Hydrock 2017 and updated 2018 Report <u>Desk Study and Ground Investigation:</u> From the walkover it was stated that topography slopes gently west to east. The site was noted to be divided into four fields, separated by drainage ditches-oriented northwest to southeast and in use (at time of reporting) as arable agriculture (wheat). A stockpile mound of spoil was left at the south of the Site from previous excavations within the Made Ground. <u>Site Investigation:</u> The presence of potential Made Ground at the Site and wider area was considered to be a low to moderate ground gas hazard while the sensitivity of the development was considered as low (commercial).

	During the first visit methane levels at 0.7 %v/v with a gas flow of 4.9 l/hr were encountered in BH03 (off-Site to the southwest). However, during subsequent visits the concentration of methane, and the flow, had decreased significantly. Whilst risks to construction workers were not generally discussed in that report, it was recommended that all contractors and maintenance workers should be made aware of the possible presence of carbon dioxide and should take all necessary health and safety precautions when working in trenches or confined spaces. Soil leachate and ground water were sent for laboratory testing for a number of contaminants, these being general inorganics, total phenols, speciated PAHs, total PAHs, metals (arsenic, boron, chromium (III, hexavalent), beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc), BTEX (benzene, toluene, ethylbenzene and xylene), TPHs and pesticide and herbicide. Slight exceedances of boron were recorded in the topsoil when compared to adopted screening criteria for plant life. The report concluded that for the Site and wider area (known as Phase 2) there was no significant risk to human health, plant growth or controlled waters and that there was a low risk (CS1) from ground gases (subject to on-going monitoring at time of reporting). <u>Geotechnical</u> Within the Hydrock Report, the Raised Marine Deposits are described as being highly compressible and it would be expected that land raising, and subsequent loading would cause significant displacement of the ground surface. As such ground improvement techniques would be required to limit the post construction settlement to within acceptable limits, utilising pre- loading or surcharging to mitigate settlement caused by the land raising exercise. Hydrock also summarised the potential for long term secondary (creep) settlement which is likely to continue beyond primary loading due to no established relationship with loading stress and can affect structures not supported by piles or rigid inclusions installed beneath the Raised Marine Deposits. It was concluded that pre-loading or surcharging of materials would not be suitable for supporting ground bearing floor slabs at the Site. A piled foundation solution was recommended within the Hydrock Report based on the poor load bearing characteristics of the Raised Marine Deposits and The River Terrace Deposits, equally due to the presence of shallow groundwater encountered at the Site, it was judged that shallow foundations would not be suitable at the Site. Piled foundations were recommended to be designed to extend through the Raised Marine Deposits to extend into competent chalk below, through a combination of skin friction and end bearing. Alternatively ground improvement techniques such as controlled modulus columns or vibro-concrete columns taking into account negative skin friction were given as an alternative option to support a floor slab, transferring the load of the floor slab via either a granular load transfer platform or a flared head on the column. The feasibility and design for these options would however have to be discussed with a suitable specialist contractor. In terms of roads and pavements Hydrock recommended that following ground improvement a CBR value of 3% would likely be achieved across the development. This statement was, however caveated as there was noted to be a significant variance in CBR values across the Site, ranging from 2 – 5 % with CBR values decreasing with increased depth across the Site. Increased CBR values could be achieved though
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	lime stabilisation during the earthworks period and proof rolling at formation level, with loose and soft spots removed and replaced with engineered fill. As part of the Hydrock Investigation a series of CPT probes were undertaken by INSITU Site Investigations across the Site Development Area. A Factual report was subsequently produced, which can be found as Appendix J within the Hydrock Report. Delta-Simons Preliminary Risk Assessment 2021 Delta Simons completed a Preliminary Risk Assessment for the Site in June 2021. As part of the assessment a walkover was completed, which confirmed that the Site status had not changed from the Hydrock Site Investigation in 2017. The Site was still vacant and appeared to be used for agricultural purposes. Several land drains were identified across the southern field. There was considered to be a low risk of enforcement action under Part 2A, and the potential for legal action from surround landowners based on the potential for contamination to migrate off Site was deemed low. A low risk of soil and groundwater contamination was identified along with a low risk of hazardous ground gas. Based on this, no further ground investigation in terms of addressing contamination impacts was deemed necessary. Geotechnical risks were however identified. It was established that instability of sediments including the Raised Marine Deposits and River Terrace Deposits may lead to excessive settlements when loads applied during redevelopment. Shallow groundwater was also highlighted as a potential development risk due to the potential flood risk. The Site was also located within a Flood Zone 2 and 3. Utilising data from the former Hydrock Investigation and desk study information from the preliminary risk assessment, it was recommended that an intrusive investigation be undertaken to inform foundation design and soakaway design.
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2.2 Preliminary Conceptual Site Model

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

Source(s)	Pathway(s)	Receptor(s)	Risk Rating	Justification & Mitigation (if required)
Pesticides and Herbicides Construction activities e.g. heavy machinery Potential On-Site Made Ground	Direct contact, ingestion or inhalation of soil bound contaminants. Inhalation of organic vapours. Migration of ground gas / vapours into on-site buildings Leaching of contamination into groundwater followed by migration or discharge to surface waters. Direct contact between aggressive ground conditions and new infrastructure.	Construction workers. Adjacent Site users and adjacent residents). Future Site users and maintenance workers. The Ryebank Rife and Lidsey Rife water courses. The underlying Secondary A and Principal Aquifers. The Built Environment (new buildings and infrastructure / utilities).	Low	Based on the findings of the previous ground investigation no elevated contaminations (except boron) have been identified in the shallow soils and groundwater. The results of gas monitoring have characterised the gassing regime at the Site as CS1. Based on the current and historical use of the Site for use as an agricultural field combined with the more recent use partially for the construction of the adjacent A279 the risk assessment has not identified any significant sources to be present. Should localised areas of elevated contaminants be present then risks to users of the Site will be mitigated by the nature of the development with risks to construction workers mitigated by the adoption of a safe working procedures good standards of personal hygiene and appropriate levels of personal protective equipment (PPE). No specific gas protection measures are considered necessary within the development however a watching brief should be maintained throughout the works for unanticipated contamination.

Source(s)	Pathway(s)	Receptor(s)	Risk Rating	Justification & Mitigation (if required)
Railway line	Direct contact, ingestion or inhalation of soil bound contaminants. Inhalation of organic vapours. Migration of ground gas / vapours into on-site buildings Leaching of contamination into groundwater followed by migration or discharge to surface waters.	Construction workers. Adjacent Site users and adjacent residents). Future Site users and maintenance workers. The Ryebank Rife and Lidsey Rife water courses. The underlying Secondary A and Principal Aquifers.	Low	The adjacent railway line is unlikely to have a significant detrimental impact upon the site and no further assessment is considered necessary.

3.0 Site Investigation

3.1 Intrusive Investigation

Delta-Simons carried out intrusive investigation works from 12th to the 30th April 2021 to provide geotechnical information for foundation parameters. Additionally, intrusive investigation work was carried out within the proposed flood compensation area to assess and inform geotechnical properties of material designated to be used as engineered fill and environmental suitability for use.

In March 2021 Delta-Simons carried out a limited Environmental Due Diligence ground investigation at the Site, the results of which are included within the assessment below to complement the data collected.

3.1.1 Health & Safety Considerations

A utilities clearance specialist attended the site on 12th April 2021 to trace services on and around the main development area prior to excavation of exploratory hole locations. Further utilities clearance was undertaken on the 21st April 2021 to trace services on and around the Flood Compensation Area.

An initial assessment of the development area and the Flood Compensation Area identified a Low risk in relation to Unexploded Ordnance (UXO) and so no specific precautionary measures were required for the works.

Future Contractors should undertake their own assessment of UXO risk in relation to their specific proposed scope of works.

A Preliminary UXO Assessment for the main development area and Flood Compensation Area is included within this report as Appendix B.

3.2 Scope of Ground Investigation and Rationale

3.2.1 Scope

The ground investigation comprised the following items:

- ▲ Supervision of all works by a Delta-Simons Geo-Environmental engineer. All intrusive locations were logged to BS 5930:2015+A1:2020 Code of Practice for Site Investigations; and in general accordance with C574 (Engineering in Chalk)

Main Development Area

- ▲ Excavation of nine trial pits (CBR01 to CBR17 inclusive and TP111 and TP112) to a maximum depth of 3.00 m bgl.
- ▲ Construction of two BRE365 Soakaways to a maximum depth of 3.0 m bgl (SA01 to SA02).
- ▲ Drilling of six boreholes utilising cable percussive and rotary techniques (CP01 to CP06 inclusive) to a maximum depth of 35 m bgl; and,
- ▲ Thirteen California Bearing Ratio, Plate Loads Tests (CBR01 – CBR13 inclusive).

Flood Compensation Area

- ▲ Excavation of seventeen trial pits (TP201 to TP207, TP209 to TP212, TP214, TP216 to TP220) to a maximum depth of 3.00 m bgl.

3.2.2 Rationale

Site Development Area		
Location	Rationale	Key Contaminants of Concern
CP01 – CP06	Targeting the proposed building footprints within the development area (warehouse and multi deck van storage) targeting the Undifferentiated Chalk Formation for the purpose of geotechnical testing and geotechnical sampling.	N/A
SA01 – SA01	Targeting shallow soils for the purpose of informing soakaway parameters.	N/A
CBR01 – CBR13	Targeting shallow soils for the purpose of road and pavement design.	N/A
CBR11 – CBR17 and TP111, TP112	Targeting the proposed building footprints within the development area (warehouse and multi deck van storage) targeting the shallow Raised Marine Deposits for the purpose of geotechnical testing and strata depth identification.	N/A
Flood Compensation Area		
TP201 to TP207, TP09 to TP212, TP14, TP16 to TP20	Targeting the Raised Marine Deposits and shallow Undifferentiated Chalk Formation to assess and inform geotechnical properties of material designated to be used as engineered fill.	Heavy Metals Hydrocarbon Fractions, PAHs, Asbestos Screen and Pesticides and Herbicides.

3.2.3 Limitations

The following Site-specific limitations were encountered during the investigation:

Site Development Area

- Due to the presence of hard strata within the Undifferentiated Chalk Formation, boreholes CP01 planned for a completion at 35m bgl was terminated at 16m bgl. Additionally, CP05 planned for completion at 35 m bgl, was terminated at 21.5 m bgl. Based on these refusals, Delta-Simons instructed rotary open hole drilling techniques to be employed, carrying out SPTs at 1.5 m intervals until the target depth of 35 m bgl was achieved.

Flood Compensation Area.

- Due to the presence of a medium pressure gas main located within the proposed FCA area running east to west along the northern boundary of this area, identified during preliminary searches an easement of 15 m either side of the asset was adhered to by Delta-Simons, limiting the investigative area.

3.3 Ground Investigation Factual Data

The investigation locations were surveyed in by the appointed surveying contractor to an accuracy of approximately +/- 0.1m. The following Site location plans have been produced as Figures 2, 2a and 2b:

- A Site wide intrusive exploratory hole location plan is presented as Figure 2.
- A main development area exploratory hole location plan is presented as Figure 2a
- A Flood Compensation Area hole location plan is presented as Figure 2b

Delta-Simons engineer verified borehole logs are presented as Appendix C, the SPT Calibration Certificates, in accordance with *BS EN ISO 22476-3:2005 (incorporating corrigendum No. 1 2007)*, *Geotechnical investigation and testing - Field testing - Part 3: Standard penetration test for SPT trip hammers* are provided in Appendix D.

3.4 In-Situ Testing and Sampling

SPT tests were undertaken in all boreholes at 1.0 m intervals until 5.0 m bgl, then every 1.5 m bgl thereafter. The results of these tests are presented in the borehole logs included as Appendix C. Corrected SPT values are shown in Figure 3.

Hand vane shear tests were undertaken on cohesive soils encountered within trial pits. Test results are shown on the borehole and trial pit logs presented in Appendix C.

Sampling comprised disturbed tub and jar samples as detailed on the borehole logs.

The results of the CBR tests, and logs of the soils encountered are included in Appendix E.

3.5 Geotechnical Laboratory Testing

A selection of soil samples were submitted to the UKAS accredited laboratory for a range of geotechnical testing, the results of which are included in Appendix F.

The programme of geotechnical testing undertaken on samples obtained from the natural soils is presented within the table below. The purpose of the laboratory testing was to assess the classification properties of the soils encountered in order to inform the outline geotechnical design advice.

Site Development Area		
Analysis	No. Tested	Rationale
Moisture content	28	To enable geotechnical assessment of cohesive soils
Plastic and liquid limits	28	To enable geotechnical assessment of cohesive soils
Particle size distribution	5	To enable geotechnical assessment of granular soils
Saturation Moisture Content of Chalk	7	To enable geotechnical assessment of chalk soils.
Oedometer Colonisation	4	To enable geotechnical assessment of cohesive soils
Undrained Triaxial Shear Strength	3	To enable geotechnical assessment of cohesive soils
pH, Sulphur, Sulphate, Water Soluble Sulphate	14	To enable concrete design in aggressive ground.
Flood Compensation Area		
Analysis	No. Tested (combined sample)	Rationale
Moisture content	15 (7)	To enable geotechnical assessment of cohesive soils
Plastic and liquid limits	15 (7)	To enable geotechnical assessment of cohesive soils
Particle size distribution	11 (7)	To enable geotechnical assessment of cohesive soils
pH, Sulphur, Sulphate, Water Soluble Sulphate	12 (8)	To enable geotechnical assessment of cohesive soils
OMC/ MDD relationship	10 (7)	To enable geotechnical assessment of cohesive soils
Hand Shear Vane at OMC	10 (7)	To enable geotechnical assessment of cohesive soils
Organic Matter	9 (6)	To enable geotechnical assessment of cohesive soils
OMC / MDD with 0.5 %Lime	(7)	To enable geotechnical assessment of cohesive soils in relation to lime consumption to assess ground improvement techniques.

OMC / MDD with 1 %Lime	(8)	To enable geotechnical assessment of cohesive soils in relation to lime consumption to assess ground improvement techniques.
OMC / MDD with 2 %Lime	(7)	To enable geotechnical assessment of cohesive soils in relation to lime consumption to assess ground improvement techniques.
Lime Consumption Test	(7)	To enable geotechnical assessment of cohesive soils in relation to lime consumption to assess ground improvement techniques.

3.6 Environmental Sampling, In-Situ Testing and Laboratory Analysis

Soils collected for laboratory analysis were placed in a variety of containers appropriate to the anticipated testing suite. Samples were stored in accordance with Delta-Simons' quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination. Records of the samples taken as part of the site investigation works, including their depths and location, are included within the exploratory hole records in Appendix C.

Three groundwater samples were collected from CP02, CP04 and CP06 on the 12th May 2021. The groundwater samples were collected using a dedicated disposable bailer.

Samples analysed for environmental purposes were placed in chilled cool boxes on site and transported to the laboratory for analysis on completion of the groundwater sampling visit.

The rationale for chemical analysis is presented in the table below and the results of the chemical laboratory testing are included in Appendix G and H.

Site Development Area			
Analytes	No. of Samples Tested		Rationale
	Soil	Ground water	
Asbestos	4	-	Common potential contaminant found in Made Ground. Tests carried out on unanticipated made ground identified within the Main Development area.
pH, As, Cd, Cu, Cr, Hg, Pb, Ni, Zn, speciated Polycyclic Aromatic Hydrocarbons (PAH)	4	3	Potential contaminants of concern, common to many sites.
Total Petroleum Hydrocarbons, Criteria Working Group Method (TPHCWG), Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	4	3	Potential contaminants of concern, common to many sites.
pH, sulphate	4		Used to assess sulphate content to enable concrete design in aggressive ground
BRES1		3	Used to assess sulphate content to enable concrete design in aggressive ground
Flood Compensation Area			
Analytes	No. of Samples Tested		Rationale
	Soil	Ground water	

Asbestos	11	-	Common potential contaminant found in made ground. -
pH, As, Cd, Cu, Cr, Hg, Pb, Ni, Zn, speciated Polycyclic Aromatic Hydrocarbons (PAH)	11		Potential contaminants of concern, common to many sites.
Total Petroleum Hydrocarbons, Criteria Working Group Method (TPHCWG), Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	11		Potential contaminants of concern, common to many sites.
pH, sulphate	11		Used to assess sulphate content to enable concrete design in aggressive ground
Combined Organochlorine and Organophosphorus Pesticides (OCOPP) and Herbicides	8		To assess the impact of current and historical agricultural activities on the site. Note that pesticides are unlikely to be present on pastureland but may be associated with arable farming which may have occurred on site during its history.

3.7 Monitoring Programme

Five rounds of groundwater level and ground gas monitoring have been undertaken on both newly installed wells and historic Delta Simons and Hydrock wells between 8th March 2021 and 7th July 2021. Measurements of the depth to groundwater within the monitoring wells were taken using an electronic dip meter. The groundwater level monitoring sheets are included as Appendix I.

To characterise the ground gas regime at the site, an infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO₂), methane (CH₄) and oxygen (O₂) in percentage by volume. Initial and steady state concentrations were recorded. The atmospheric pressure before and during monitoring, together with the weather conditions, was recorded. All monitoring results obtained to date together with the temporal conditions are contained within Appendix I..

4.0 Ground Summary

4.1 Introduction

The sections below summarise the ground and groundwater conditions encountered during the Delta-Simons 2021 site investigations and also incorporates data previously produced by Hydrock during their Site investigation in October 2017.

4.2 Ground Model

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

4.2.1 Main Development Area

Summary of Observed Ground Conditions				
Strata	Typical Strata Description	Depth Range of Strata Base (m bgl)	Maximum Proven Thickness (m)	Comments
Topsoil	Grass over soft to firm brown slightly gravelly slightly sandy clay	0.30 – 0.70	0.70	Encountered at all locations
Made Ground	Soft to firm brown slightly gravelly sandy clay. Gravel is fine to coarse sub angular to sub rounded of flint, concrete, and red brick. Cobbles are angular of redbrick and concrete Rare ceramic tile. Rare rootlets.	0.50	0.40	Only encountered within CBR05, CBR08, CBR09, BH07 (Hydrock – TP129- north of Site)
Raised Marine Deposits	Frequently recovered as soft light grey and brown slightly sandy gravelly silty clay with horizons of fine sand and organic matter.	1.50 – 6.00	5.50	
Undifferentiated Chalk Formation	Structureless chalk: commonly recovered as off white slightly sandy silty gravel or sandy gravelly silt.	>35	>32.0	

4.2.2 Flood Compensation Area

Summary of Observed Ground Conditions				
Strata	Typical Strata Description	Depth Range of Strata Base (m bgl)	Maximum Proven Thickness (m)	Comments
Topsoil	Grass/ agricultural crop over soft to firm brown slightly gravelly slightly sandy CLAY	0.35 – 0.50	0.50	Absent at TP203, and TP218
Made Ground	Soft to firm brown slightly gravelly sandy clay. Gravel is fine to coarse sub angular to sub rounded of flint, concrete, and red brick. Cobbles are angular of redbrick and concrete Rare ceramic tile. Rare rootlets.	0.70	0.70	Only encountered within TP203, TP218

River Terrace Deposits	Firm orangish brown slightly gravelly slightly sandy silty clay with a low cobble content. Gravel is sub angular fine to medium of flint. Occasional pockets of brown and black organic matter up to Sand is fine to medium.	0.90 – >3.00	>2.50	Base not proven in all locations
Undifferentiated Chalk Formation	Structureless chalk recovered as slightly sandy silty sub angular to sub rounded fine to coarse gravel with a low cobble content.	>3.00	>2.10	

Inferred geological sections from the Delta Simons Site investigation are included within this report as:

- ▲ Figure 4a – Main Development Area Cross section (Delta Simons Investigation)
- ▲ Figure 4b – Flood Compensation Area Cross section (Delta Simons Investigation)

Plots of inferred topsoil, Raised Marine Deposit and River Terrace Deposit thicknesses are included as Figure 5– 5c for the Main Development Area and the Flood Compensation Area.

4.3 Visual and Olfactory Evidence of Contamination - Soils

No visual or olfactory evidence of potential gross contamination was observed during the Delta-Simons investigations and nor during 2017 Hydrock Investigation.

4.4 Groundwater

4.4.1 Strikes During Investigations

Groundwater strikes recorded as excavations progressed during the ground investigation within the Main Development Area range from 0.90 to 2.50 m bgl (-0.92m to 0.17m AOD) within the Raised Marine Deposits and 3.00 to 9.50 m bgl (-1.97 to -8.63m AOD) within the Undifferentiated Chalk. The groundwater strikes during drilling are summarised below.

Site Development Area				
Exploratory Hole	Water strike during drilling (m bgl)	Water strike during drilling (m AOD)	Stratum	Comment
CP01	3.00	-1.97	Undifferentiated Chalk	Rose to 2.50 m bgl after 20 minutes
CP02	4.50	-3.40	Undifferentiated Chalk	Rose to 1.70 m bgl after 5 minutes
CP03	2.00	-0.92	Raised Marine Deposits	Rose to 0.40 m bgl after 20 minutes
CP03	6.00	-4.92	Undifferentiated Chalk	Rose to 2.17 m bgl after 20 minutes
CP04	4.50	-3.52	Undifferentiated Chalk	Rose to 0.90 m bgl after 20 minutes
CP05	5.00	-4.13	Undifferentiated Chalk	Rose to 1.38 m bgl after 20 minutes
CP05	9.50	-8.63	Undifferentiated Chalk	Rose to 5.40 m bgl after 20 minutes
CP06	4.80	-3.67	Undifferentiated Chalk	Rose to 0.90 m bgl after 5 minutes
CP06	9.00	-7.87	Undifferentiated Chalk	Rose to 1.00 m bgl after 20 minutes

BH02	5.30	-4.15	Undifferentiated Chalk	
BH03	5.00	-3.90	Undifferentiated Chalk	
BH04	5.00	-3.54	Undifferentiated Chalk	
BH05	5.00	-4.08	Undifferentiated Chalk	
BH06	5.00	-4.03	Undifferentiated Chalk	
BH07	4.00	-2.61	Undifferentiated Chalk	
BH08	5.50	-4.41	Undifferentiated Chalk	
VP02	1.50	-0.42	Raised Marine Deposits	
VP03	0.90	0.10	Raised Marine Deposits	
VP04	1.00	0.17	Raised Marine Deposits	
VP05	1.70	-0.85	Raised Marine Deposits	
VP06	0.90	0.04	Raised Marine Deposits	
CBR11	1.80	N/A	Raised Marine Deposits	Elevation data not recorded
CBR13	2.50	N/A	Raised Marine Deposits	Elevation data not recorded
CBR16	3.00	N/A	Undifferentiated Chalk	Elevation data not recorded

Groundwater strikes recorded as excavation progressed during the site investigation within the Flood Compensation Area range from 2.70 to 3.00 m bgl (-0.23 to 0.25 m AOD) within the Undifferentiated Chalk Formation. The groundwater strikes during drilling are summarised below.

Flood Compensation Area				
Exploratory Hole	Water strike during drilling (m bgl)	Water strike during drilling (m AOD)	Stratum	Comment
TP204	3.00	-0.23	Undifferentiated Chalk	
TP205	3.00	0.25	Undifferentiated Chalk	
TP206	2.70	0.03	Undifferentiated Chalk	

4.4.2 Strikes During 2017 Hydrock Investigation

Groundwater data from the 2017 Hydrock report indicates that Groundwater strikes were encountered within:

- ▲ The Raised Marine Deposits/ River Terrace Deposits ranging from, 1.00 – 4.50 m bgl
- ▲ The Undifferentiated Chalk Formation ranging from 1.50 – 5.50 m bgl

4.4.3 Levels During Monitoring Programme

In order to understand the groundwater regime and seasonal fluctuations given the shallow nature of the groundwater levels recorded to date, continuous Groundwater data level loggers were installed in Delta-Simons boreholes constructed during the previous Due Diligence investigation on the 16th April 2021 and installed in newly constructed boreholes on the 12th May 2021.

Data loggers were installed in BH03, BH04 and BH08 on the 16th April 2021 to monitor groundwater levels within response zones set in the shallow Undifferentiated Chalk Formation, which was anticipated to be in hydraulic continuity with the Raised Marine Deposits above. Additionally, data loggers were installed into newly installed boreholes CP03, CP04 and CP06 with response zones set at depth within the deeper Undifferentiated Chalk to assess groundwater characteristics of the deeper aquifer.

Analysis of the recovered data loggers showed that ground water levels fluctuated between 0.69 and 1.43 m bgl (0.03 and 0.33 m AOD) during the monitoring period. Groundwater levels were shown to vary slightly as a result of weather events when compared against Met Office rainfall data. It was established that increased rainfall in May 2021 resulted in a decrease in depth to groundwater across the Site in data recorded in early June. Groundwater was then found to increase in depth during drier periods in late June and early July 2021.

As part of a previous due diligence exercise, monitoring wells were installed across Main Development Area with response zones set in the Raised Marine Deposits and shallow Undifferentiated Chalk Formation. These locations were monitored between the 18th March and 7th July 2021 with the results included as Appendix I.

Monitoring data and LNAPL measurements are provided in Appendix I and summarised in the table below.

Exploratory Hole	Response Zone		Water level during monitoring Max to Min Range		LNAPL Y/N	Stratum
	m bgl	m AOD	m bgl	m AOD.		
VP02	0.60 - 1.80	-0.72 - 0.48	0.45 - 0.89	0.63 - 0.19	N	Raised Marine Deposits
VP03	0.60 - 1.80	-0.80 - 0.40	0.63 - 0.82	0.37 - 0.18	N	Raised Marine Deposits
VP04	0.60 - 1.80	-0.63 - 0.57	0.63 - 1.22	0.54 - -0.05	N	Raised Marine Deposits
VP05	0.60 - 1.80	-0.95 - 0.25	0.35 - 0.68	0.50 - 0.17	N	Raised Marine Deposits
VP06	0.60 - 1.80	-0.86 - 0.34	0.25 - 0.87	0.69 - 0.07	N	Raised Marine Deposits
BH01S	0.50 - 1.30	0.84 - 1.64	1.43 - 1.88	0.71 - 0.26	N	Raised Marine Deposits
BH01D	1.50 - 6.00	-3.86 - 0.64	1.58 - 1.89	0.56 - 0.25	N	Undifferentiated Chalk Formation
BH02S	1.00 - 2.00	-0.85 - 0.15	0.67 - 1.0	0.48 - 0.15	N	Raised Marine Deposits
BH02D	5.00 - 7.00	-5.85 - -3.85	0.7 - 1.03	0.45 - 0.11	N	Undifferentiated Chalk Formation
BH03S	1.00 - 3.00	-1.90 - 0.10	0.6 - 0.93	0.50 - 0.17	N	Raised Marine Deposits
BH03D	4.50 - 7.00	-5.90 - -3.40	0.72 - 0.96	0.38 - 0.14	N	Undifferentiated Chalk Formation
BH04S	0.30 - 1.10	0.36 - 1.16	0.89 - 1.01	0.57 - 0.46	N	Raised Marine Deposits
BH04D	1.50 - 5.00	-3.54 - -0.04	1.01 - 1.25	0.45 - 0.22	N	Undifferentiated Chalk Formation
BH05S	0.50 - 2.00	-1.08 - 0.42	0.51 - 0.73	0.41 - 0.19	N	Raised Marine Deposits
BH05D	4.00 - 7.00	-6.08 - -3.07	0.51 - 0.73	0.41 - 0.19	N	Undifferentiated Chalk Formation
BH06S	1.00 - 2.00	-1.03 - -0.03	0.72 - 0.84	0.25 - 0.13	N	Raised Marine Deposits
BH06D	4.00 - 7.00	-6.03 - -3.03	0.64 - 0.98	0.33 - -0.01	N	Undifferentiated Chalk Formation
BH07S	0.50 - 2.00	-0.61 - 0.89	0.92 - 1.2	0.47 - 0.19	N	Raised Marine Deposits
BH07D	2.50 - 6.00	-4.61 - -1.11	0.96 - 1.2	0.47 - 0.19	N	Undifferentiated Chalk Formation
BH08S	1.50 - 3.00	-1.91 - -0.41	0.61 - 0.85	0.48 - 0.24	N	Raised Marine Deposits
BH08D	4.00 - 7.00	-5.91 - -2.91	0.61 - 0.89	0.48 - 0.20	N	Undifferentiated Chalk Formation
CP02	14.50 - 17.0	-15.9 - -13.4	0.93 - 0.93	0.17 - 0.17	N	Undifferentiated Chalk Formation
CP03	20.0 - 23.0	-21.92 - -18.92	0.89 - 0.91	0.17 - 0.19	N	Undifferentiated Chalk Formation
CP04	17.0 - 19.0	-18.03 - -16.03	0.87 - 0.87	0.10 - 0.10	N	Undifferentiated Chalk Formation

Exploratory Hole	Response Zone		Water level during monitoring Max to Min Range		LNAPL Y/N	Stratum
	m bgl	m AOD	m bgl	m AOD.		
CP06	17.0 – 20.0	-18.87 - -15.87	0.85 - 0.86	0.27 - 0.28	N	Undifferentiated Chalk Formation
BH03HY (Hydrock Borehole)	3.00 - 10.0	-8.89 - -1.89	1.66 - 1.66	-0.55 - -0.55	N	Raised Marine Deposits
BH04HY (Hydrock Borehole)	2.00 - 10.0	-9.12 - -1.12	0.68 - 0.68	0.2 - 0.2	N	Raised Marine Deposits
BH05HY (Hydrock Borehole)	3.00 – 5.00	-4.11 - -2.11	0.75 - 1.75	0.14 - -0.86	N	Raised Marine Deposits

Groundwater levels within the Raised Marine Deposits during monitoring varied between 0.25 and 1.88m bgl (-0.05 – 0.71m AOD) and within the Undifferentiated Chalk between 0.51 and 1.89m bgl (-0.86 to 0.56m AOD).

4.4.4 Hydrock Groundwater Levels Monitoring Programme

Hydrock monitored a selection of boreholes between the 9th May 2017 and 29th June 2017 in the Main Development Area and to the South of the Site with response zones located across the Raised Marine Deposits and Undifferentiated Chalk Deposits.

Groundwater levels were recorded between 0.41m bgl and 0.73m bgl within the Raised Marine Deposits

In addition to the ground investigation report produced by Hydrock in 2017, Delta-Simons were additionally provided with a Winter Groundwater Monitoring Data Sheet produced by Hydrock. The data sheet indicates that a selection of boreholes constructed during the Site investigation in 2017 in the Main Site Area were monitored, (BH02 – BH06). Additionally, two new boreholes were constructed across the Main Development Area, (WS201, WS202) two boreholes were also constructed within the Flood Compensation Area (WS203A and WS204) in January 2021.

Although Delta-Simons were not provided with borehole logs for the newly installed boreholes, it has been assumed that response zones were set in the Raised Marine Deposits within the Main Site Area and response zones were set within the River Terrace Deposits within the Flood Compensation Area.

The winter groundwater monitoring programme was undertaken between the 26th November 2020 and 17th February 2021.

Between 26th November and 17th February 2021, groundwater within the Raised Marine Deposits from boreholes situated within the Main Site Development area ranged between 0.00 and 2.34 m bgl (-0.43 – 1.26 m AOD).

Between the 29th January and 17th February 2021, groundwater within the River Terrace Deposits from boreholes situated within the FCA area were recorded between 0.47 – 2.50 m bgl (-0.11 – 2.15 m AOD).

From the reported data during the winter monitoring programme, groundwater is considered to have been consistently high, decreasing in depth towards February. This corresponds with witnessed conditions on Site, where waterlogged ground and surface flooding was identified.

4.5 Visual and Olfactory Evidence of Contamination - Groundwater

No visual or olfactory evidence of potential gross contamination was observed during the Delta-Simons or Hydrock investigation.

4.6 Material Properties

The table below summarises the factual material properties based upon the results of In-Situ and laboratory test data and where appropriate provides derived geotechnical parameters from Delta-Simons Investigation and Hydrock's 2017 Investigation.

4.6.1 Site Development Area

Site Development Area				
Parameter	Raised Marine Deposits (Delta-Simons)	Raised Marine Deposits (Hydrock)	Undifferentiated Chalk Formation (Delta-Simons)	Undifferentiated Chalk Formation (Hydrock)
Moisture Content - w	18-51	14-78		15 - 28
Saturated Moisture Content			20 - 27	21 - 26
Liquid Limit - owl	25-71	26 - 78	28 - 39	
Plastic Limit - wP	14-41	16 - 28	17 - 22	
Plasticity Index - IP	11-41	5 - 50	10 - 17	4 -19
Bulk Unit Weight - γ	19.73 – 20.40	16.38 – 18.64	18.93 – 20.50	
Bulk Density	1.81 – 2.08	1.67 – 1.83	1.93 – 2.09	
Dry Density	1.30 – 1.65	1.08 – 1.33	1.57 – 1.76	1.52 – 1.73
Uncorrected SPT N Value	0 – 10	0 - 20	0 – 50	2 – 49
Corrected ¹ SPT (N60)	0 – 10.3		0 – 50	
Undrained Shear Strength ² – cu – Laboratory	23 -33	5 - 25		
Shear Strength – cu – Hand Shear Vane	10 – 70			
One Dimensional Consolidation - Mv	0.32 – 1.30	0.30 – 1.11		
Notes:				
1. SPT N values corrected for energy delivered to drive rods utilising the determined energy ratio (Er): $N60 = (Er \times N)/60$ after BS EN ISO 22476-3:2005 [Ref. 5]				
2. From laboratory test results				

Location	Depth	Sample Properties % Dry Mass				BS5930 soil description
		Very Coarse	Gravel	Sand	Fines	
SA01	1.00	0	17	25	59	Gravelly very sandy clay
CP04	2.00	0	1	8	91	Sandy clay
CP04	3.00	0	6	37	56	Slightly gravelly sandy clay
CP05	2.00	0	0	5	95	Sandy clay
CP05	3.00	0	0	5	95	Sandy clay

4.6.2 Flood Compensation Area

Flood Compensation Area				
Parameter	River Terrace Deposits (Delta-Simons)	River Terrace Deposits (Hydrock)	Undifferentiated Chalk Formation (Delta-Simons)	Undifferentiated Chalk Formation (Hydrock)
Moisture Content - w	13 - 23	12 - 21	17 - 24	
Saturated Moisture Content				
Liquid Limit - w _L	23 - 44	25 - 42	26 - 32	
Plastic Limit - w _P	13 - 22	16 - 22	16 - 20	
Plasticity Index - IP	10 - 25	9 - 22	11 - 12	
Shear Strength – cu – Hand Shear Vane	48 - 84			
Maximum Dry Density	1.71 - 1.86		1.66 - 1.73	
As Received Moisture Content	17 - 23		19 - 23	
Optimum Moisture Content	13 - 18		16 - 23	

Due to the scale and nature of the proposed earthworks within the FCA it is envisaged that materials from the same strata will be combined as part of the excavation process and therefore composite samples have been produced in localised areas to reflect anticipated real-world conditions.

Samples from these areas were then subject to a series of earthworks classification testing, a summary of which is presented overleaf.

Location	Depth (m)	Strata	Sample Properties Dry Mass %					BS5930 Soil Description
			Very Coarse	Gravel	Sand	Silt	Clay	
TP201	1.0 - 1.20	River Terrace Deposits	0	5	21	49	29	Slightly gravelly sandy clayey silt
TP205	1.0 - 1.20		0	15	20	44	21	Gravelly sandy clayey silt
TP209	2.0		0	49	17	23	11	Sandy clayey silty gravel
TP209	1		0	0	11	57	32	Sandy clayey silt
TP211	1.0 - 1.20		9	29	24	25	13	clayey very silty very sandy gravel
TP211	3.0		0	34	28	25	13	Clayey silty sandy gravel
TP212	1.0 - 1.20		0	2	18	49	31	Gravelly sandy very clayey silt
TP217	1.0 - 1.20		0	0	5	66	29	slightly sandy clayey silt
TP218	3.0		0	10	28	41	21	Clayey very sandy silt
TP218	1.0		0	1	22	51	26	Slightly gravelly Sandy very clayey silt
TP217 - TP201	1.0 - 3.0		6	10	17	44	23	Gravelly sandy clayey silt
TP219 - TP203	1.0 - 2.20		0	2	17	54	27	Gravelly sandy clayey silt
TP220 - TP206	1.0 - 2.20		0	25	23	34	18	Clayey very gravelly very sandy silt
TP214 - TP210	1.0 - 3.0		0	8	30	40	22	slightly gravelly clayey very sandy silt
TP211 - TP207	1.0 - 2.20		0	24	25	37	14	clayey very gravelly very sandy silt
TP209	3.0	Undifferentiated Chalk	0	27	19	37	17	sandy clayey very gravelly silt
TP205	2.0 - 2.20		0	40	18	27	15	Sandy silty clayey gravel
TP205 - TP206	2.90 - 3.0		0	46	21	23	10	clayey very gravelly very sandy silt
TP219 - TP204	2.0 - 2.20		16	38	15	21	10	Slightly clayey sandy silty gravel

Based on the above table, the River Terrace Deposits within the Flood Compensation Area were found to predominantly comprise silt with variable proportions of sand and gravel, locally recorded in places as silt sandy gravel.

Maximum Dry Density values of the River Terrace Deposits were also recorded between 1.71 Mg/m³ and 1.86 Mg/m³ indicating a slight variability in the composition of the material.

Maximum Dry Density values of the Undifferentiated Chalk Deposits were also recorded between 1.66 Mg/m³ and 1.80Mg/m³ indicating a slight variability in the composition of the material but generally homogenous.

Based on anticipated re-use of these materials to raise the Main Development Area by approximately 2m, lime consumption tests were completed on seven combined samples to understand the percentage of lime which may be needed to raise the pH of the material above 12. At this point it is judged that any further addition of lime will not be used to raise the pH, but instead will begin to react with the clay. A summary of the results are presented below.

Initial Consumption of Lime (River Terrace Deposits)							
pH at Lime Content	TP217-TP201 1.0-3.0 m bgl	TP219-TP203 1.0-2.20 m bgl	TP220-TP206 1.0-2.20 m bgl	TP214-TP210 1.0 -3.0 m bgl	TP211-TP207 1.0-2.20 m bgl	TP205-TP206 2.90-3.00 m bgl	TP219-TP204 2.00-2.20 m bgl
pH at lime content 1%	12.0	12.1	11.9	11.8	11.9	12.7	12.6
pH at lime content 2%	12.1	12.1	12.0	11.9	12.0	12.8	12.6
pH at lime content 3%	12.1	12.1	12.1	12.0	12.0	12.8	12.7
pH at lime content 4%	12.1	12.1	12.1	12.0	12.0	12.8	12.7
pH at lime content 5%	12.1	12.2	12.1	12.0	12.0	12.8	12.7
pH at lime content 6%	12.1	12.2	12.1	12.0	12.0	12.9	12.7

4.7 Geochemical Testing

4.7.1 Site Development Area

Geochemical analysis was undertaken on a series of samples from the Main Development Area from the River Terrace Deposits and tested for selective contaminants (BRE Special Digest 1:2005 (3rd Edition), Concrete in Aggressive Ground, the results of which are summarised in the table below.

Tests	No. of Tests	Minimum	Maximum
Soil - pH	11	8.3	9.2
Soil - Total Sulphur	11	<0.01%	0.20%
Soil – Acid Soluble Sulphate	11	<0.025%	<0.065%
Soil - Water Soluble Sulphate	15	0.021 g/L	0.25 g/L
Water – pH	3	7.3	7.6
Water - Sulphate	3	54 mg/L	325 mg/L

4.7.2 Flood Compensation Area

Geochemical analysis was undertaken on a series of samples from the Flood Compensation Area from the River Terrace Deposits and tested for selective contaminants (BRE Special Digest 1:2005 (3rd Edition), Concrete in Aggressive Ground, the results of which are summarised in the table below.

Tests	No. of Tests	Minimum	Maximum
Soil - pH	19	6.9	8.9
Soil - Total Sulphur	15	<0.007%	0.018%

Tests	No. of Tests	Minimum	Maximum
Soil – Acid Soluble Sulphate	15	<0.015%	<0.30%
Soil - Water Soluble Sulphate	19	0.0032 g/L	0.029 g/L
Organic Matter	14	0.3 %	3 %

4.8 Ground Gas Data

Gas monitoring results are presented in Appendix I and are summarised in the table below and encompasses ground gas data collected during the Delta-Simons Due Diligence investigation and from boreholes installed during the most recent phase of investigation. Where possible, historical Hydrock boreholes have also been monitored. In total, four rounds of gas monitoring have been undertaken between 18th March 2021 and 7th July 2021.

Five rounds of ground gas monitoring have been undertaken at the Site. Barometric pressures ranged from 1030mB (visit 1) to 1000mB (visit 4).

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		
VP01	<0.1	<0.1	<0.1	<0.1	19.8	19.8	<0.1	<0.1	0.65	1.8	RMD	No
VP02	<0.1	0.3	<0.1	0.3	20.1	21.1	<0.1	<0.1	0.6	1.8	RMD	Yes (round 1,2)
VP03	<0.1	0.3	0.1	0.7	18.4	21.1	<0.1	0.4	0.6	1.8	RMD	No
VP04	<0.1	0.3	<0.1	1.2	19.2	21	<0.1	<0.1	0.6	1.8	RMD	No
VP05	<0.1	0.3	0.3	0.6	20.2	20.4	<0.1	<0.1	0.6	1.8	RMD	Yes (round 1, 2)
VP06	<0.1	0.2	0.2	0.3	20.3	21	<0.1	<0.1	0.6	1.8	RMD	Yes (round 1)
BH01S	<0.1	0.2	0.1	2.8	18	21.5	<0.1	<0.1	0.5	1.3	RMD	No
BH01D	<0.1	<0.1	1.2	2.3	16.2	19.2	<0.1	<0.1	1.5	6	Chalk	No
BH02S	<0.1	0.3	0.2	1.3	18.9	20.3	<0.1	<0.1	1	2	RMD	Yes (round 2,3,4)
BH02D	<0.1	<0.1	0.2	0.5	20.6	20.6	<0.1	<0.1	5	7	Chalk	Yes (round 2,3,4,5)
BH03S	<0.1	86.6	<0.1	0.4	20.2	20.5	<0.1	<0.1	1	3	RMD	Yes (round 2,3,4,5)
BH03D	<0.1	<0.1	0.1	0.1	20.7	20.7	<0.1	<0.1	4.5	7	Chalk	Yes (round 2,3,4,5)
BH04S	<0.1	0.3	0.2	3.8	16.7	20.8	<0.1	<0.1	0.3	1.1	Chalk	No
BH04D	<0.1	<0.1	0.1	0.1	20.5	20.6	<0.1	<0.1	1.5	5	Chalk	Yes (round 2,3,4,5)
BH05S	<0.1	0.2	<0.1	0.5	20.2	21	<0.1	<0.1	0.5	2	RMD	No

BH06S	<0.1	0.3	<0.1	<0.1	0.1	21.4	<0.1	<0.1	1	2	RMD	Yes (round 2,3,4)
BH07S	<0.1	0.2	<0.1	0.2	20.5	21.2	<0.1	<0.1	0.5	2	RMD	No
BH08S	<0.1	0.2	<0.1	3.3	18.4	20.9	<0.1	3.0	1.5	3	RMD	Yes (round 2,3,4,5)
CP06	<0.1	<0.1	<0.1	0.2	20.6	20.6	<0.1	<0.1	17	20	Chalk	Yes (round 4,5)
CP04	<0.1	<0.1	<0.1	<0.1	20.8	20.8	<0.1	<0.1	17	19	Chalk	Yes (round 4)
CP03	<0.1	<0.1	<0.1	<0.1	20.6	20.9	<0.1	<0.1	20	23	Chalk	Yes (round 4,5)
CP02	<0.1	<0.1	0.3	0.3	20.5	20.6	<0.1	<0.1	14.5	17	Chalk	Yes (round 4,5)
BH04HY	<0.1	<0.1	0.1	0.1	20.8	20.8	<0.1	<0.1	2	10	RMD	Yes (round 4)
BH03HY	<0.1	<0.1	2.2	2.2	19.5	19.5	<0.1	<0.1	3	10	RMD	Yes (round 4)
BH05HY	<0.1	<0.1	0.4	0.4	20.7	20.7	<0.1	<0.1	3	5	RMD	Yes (round 4,5)

5.0 Geotechnical Assessment

5.1 Summary of Development Proposals

The proposed development will comprise a warehouse located in the south east of the Site with a multi-storey van storage facility located to the north with further car parking located in the south west of the Site. The northern and eastern areas of the main development Site was noted to be several metres lower than the surrounding area and it is understood that Site levels will need to be raised via the importation of materials to achieve formation levels.

Due to the Site's location within a Flood Zone, it is necessary to raise Site levels by approximately 2m resulting in the requirement to import 85,700m³ of material. Drawing 2 indicates proposed final formation levels following land raising activities, with the warehouse final formation level indicated at 3.65m AOD.

It will also be necessary to provide a Flood Compensation Area (FCA) to allow for excess water to drain away from the existing development into adjacent fields during flood events. Based on initial calculations, the FCA will need to be constructed to a minimum depth of 0.9m AOD resulting in the generation of approximately 122,169m³ of material of which a proportion (sands and clay) have been designated for reuse as engineered fill. Due to the previously monitored shallow groundwater level (1m AOD) it has been assumed that soil resulting from below this level will be unsuitable for use as engineered fill as they are likely to be saturated and/or warrant significant treatment to reduce moisture contents to an acceptable level. Furthermore, it has been assumed that chalk materials won from the excavation are unlikely to be suitable for use as engineered fill due to their poor performance during periods of inclement weather. On this basis only sands and clays extracted from the River Terrace Deposits in the FCA are expected to be suitable for use as engineered fill resulting in a soil deficit for the main development and a further area to the north of the FCA has been designated for the extraction of the residual material balance.

The proposed FCA area and volumes are presented as Drawing 1 and Drawing 2.

Based on initial conversations with the Structural Engineer, it is understood that indicative column loads for the main structure will be

- ▣ Perimeter – 475kN (Dead and live)
- ▣ Internal (supporting mezzanine) – 975kN (dead and live)

Flood slab loadings are expected to be 37.5kN/m². At this stage loadings for the van deck have not been provided but are expected to be higher than the main development.

Ground conditions at the main development have been found to be broadly uniform comprising a layer of topsoil (0.5m thick) bearing onto soft grey slightly gravelly sandy clay of the Raised Marine Deposits to depths between 0.9m and 6.0m although generally 4m thick. The soil was noted to exhibit very low densities with N₆₀ values typically varying between 1 and 10 with the rods sinking under their own weight at several test locations.

Based on the mass shear strength relationship developed by Stroud, 1972 and using a conservative F_i factor of 4.2, the Raised Marine deposits are indicated to have a shear strength of between 4 and 43kN/m² with an average shear strength of 15kN/m². This has been broadly corroborated with the results of hand shear vane tests indicating values to vary between 10 and 70kN/m² whilst the results of triaxial tests have indicated values to vary between 23 and 33kN/m².

The results of the in-situ SPT testing have also been used to infer modulus of volume compressibility values between 0.21 to 2.1m²/MN whilst the results of laboratory testing have been found to vary between 0.3 and 1.3m²/MN, indicating SPT inferred values to underestimate the volume of compressibility.

The underlying solid strata was found to comprise structureless clay recovered as sandy gravel or sandy silt. In-situ SPT tests were noted to increase with depth within initial values noted to be low, increasing to >30 between 10 and 15m bgl, and refusing (>50) between 15 and 20m bgl and proven to 35m bgl.

The results of saturated moisture content/ Intact dry density were found to vary between 20 – 30 % and 1.57 – 1.76 Mg/m³ and based on table 3.2 of CIRIA 574 were considered to correspond to medium/ high density chalk.

Based on the findings of the ground investigation, the following geotechnical constraints have been identified:

- ▲ Raised Marine Deposits exhibit low shear strengths and are likely to result in excessive settlements when loaded.
- ▲ Underlying undifferentiated chalk strata was noted to exhibit a high degree of weathering within the shallow strata directly beneath the Raised Marine Deposits with competent rock noted to be present at depths between 15 and 20m bgl.
- ▲ Shallow groundwater has been historically recorded at the Site, with the development area noted to have been flooded during inclement and winter periods which may preclude construction activities.

5.2 Foundations

5.2.1 Spread Foundations

The ground investigation has identified the Raised Marine Deposits to exhibit low shear strengths and are considered to provide insufficient bearing capacities to support the use of shallow spread foundations. Deeper competent strata has been identified within the undifferentiated chalk however the thickness of the overlying Raised Marine Deposits are considered to preclude the effective use of shallow spread foundations into this deeper stratum.

On this basis, the construction of shallow spread foundations directly within the natural soils within the Main Development Area are considered suitable.

5.2.2 Volume Change Potential

The liquid limit and plasticity index results suggest that the Raised Marine Deposits are of low to high plasticity, compared with material of the River Terrace Deposits within the Flood Compensation Area which are classified as Low Plasticity. Where plasticity results were taken in the Undifferentiated Chalk deposits, results indicate that these materials have a low to intermediate plasticity. As such it can be judged that materials from the River Terrace Deposits and chalk have a potential swell classification of low and minimal volume change is likely. However, material from the Raised Marine Deposits have a low to high swell classification.

A plasticity chart is included as Figure 6.

5.2.3 Ground Improvement Techniques

Based on existing ground condition, the use of shallow spread foundations is unlikely to be a suitable founding option and the following alternative ground improvement techniques have been considered to permit the use of these techniques. As part of the assessment, Delta-Simons have made preliminarily contact with a range of ground improvement contractors seeking their professional opinion bearing in mind the ground conditions and complex earthworks programme anticipated at the Site.

Vibro Stone Replacement

Vibro Stone Replacement involves the use of a long and heavy vibrating poker to form stone columns over the depth of soil requiring treatment (likely to the full depth of the weaker soils). Structural loads may then be supported, on shallow, nominally reinforced pad and strip footings. The placement of columns under the slabs may allow a traditional ground bearing construction to be adopted.

Following discussions with a specialist vibro ground improvement contractor it is understood that the Raised Marine Deposits would be unlikely to provide sufficient constraining pressure on installed stone column which would lead to 'bulging' of the column. Consequently, it is unlikely that ground conditions could be densified to a sufficiently level to permit the use of shallow spread foundations and this technique is unlikely to provide a significant benefit.

Vibro Concrete Columns

An alternative to Vibro Stone Columns, this technique involves the construction of a concrete column through a bottom fed vibrating probe. The probe is raised and lowered while concrete is simultaneously pumped to form a bulb at the base, transferring loads into a dense end bearing strata. Concrete then fills the resulting void as the probe is removed from the void.

The soil profile encountered at the Site, is not considered to fit the profile required for this technique to be economically or practically implemented due to the depth to the competent strata. Vibro Concrete Columns are ideally suited to strata where soft material is present overlying ideally granular dense material or bedrock, where the concrete column can terminate transferring loads into the competent strata.

Controlled- Modulus- Columns

A reverse flight auger is used to drill down to competent strata while laterally displacing soils creating minimal surface spoil whilst simultaneously densifying the surrounding soils. Concrete or grout is then pumped through the hollow stem auger whilst the auger is slowly removed. The concrete then provides an unreinforced pile which allows the transfer of surface loads to the competent strata below.

Similarly, with Vibro Concrete columns, and Vibro Stone columns the anticipated loads of the development are likely to exceed the working capabilities of this technique, combined with the significant anticipated depth to competent chalk, this likely precludes the use of this technique. Further to this, Delta-Simons understand through informal conversations with ground improvement contractors, that this method of ground improvement lacks suitable modelling within chalk deposits and may present unknown limitations such as approvals from local planning authorities.

Soil stabilisation

There are several techniques available which can be broadly summarised into ex-situ and in-situ techniques. Both methods typically comprise the mixing of existing soils with cement and various stabilising materials to improve physical performance of the soils thereby increasing shear strengths and reducing settlements when the materials are loaded.

Shallow stabilisation comprising rotivation of the shallow soils and the introduction of stabilising agents can be utilised to provide a stiffened raft of material however due to the depth limitations of this technique, deeper soil strata would not be improved and foundations loading the stiffened raft may be prone to either punching through this material and or differential and excessive settlement. Alternatively, weaker soils could be excavated and stabilised ex-situ however the volume of soils likely to require stabilisation combined with the resulting depths of excavation and shallow groundwater is likely to preclude the economic feasibility of this technique.

It may be possible to undertake in-situ soil mixing using flight augers which inject and mixture stabilising compounds into the ground which then form columns of improved soil which can support imposed loads however due to the poor performance of the deeper soils this technique is unlikely to be economically viable.

5.2.4 Piling

A piled foundation solution using traditional bored or continuous flight auger (CFA) piles transferring loads to competent 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.

For preliminary design purposes, the following allowable CFA pile loads have been assessed based on commonly accepted methods and in accordance with CIRIA C574 for determining pile base resistance and skin friction/adhesion (utilising a bulk Factor of Safety of 2.5, or 3.5 for the base and 1.5 for the skin). Pile groups are assumed to be free standing with a spacing no less than three pile diameters. Commercial pile designers may use different parameters, design factors or safety factors than published methods. The values in the table

below are likely to be significantly lower where loose soils or voiding associated with dissolution features are encountered.

Estimated Allowable Pile Capacities (Bored Piles)		
Typical Pile Size/Depth		Single Pile (kN)
0.30 m diameter	10 m	140
	15 m	360
	20 m	600
	25 m	1000
	30 m	1300
0.45 m diameter	10 m	230
	15 m	600
	20 m	1000
	25 m	1600
	30 m	2160
0.6 m diameter	10 m	300
	15 m	800
	20 m	1440
	25 m	2160
	30 m	2890
0.75 m diameter	10 m	400
	15 m	1000
	20 m	1800
	25 m	2700
	30 m	3600
0.9 m diameter	10 m	470
	15 m	1200
	20 m	2160
	25 m	3250
	30 m	4330

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.

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.

An estimated allowable pile capacity chart is included as Figure 7.

5.2.5 Floor Slabs

It is understood that site levels will be raised using engineered fill prior to the construction of the proposed development scheme. The imposition of additional loads by structural engineered fill is likely to result in soil movement which will be addressed within the earthworks section however additional imposed loads by a floor slab exerting loads up to 37.5kN/m² may result in further settlement of the underlying soils and hence the use of ground bearing floor slabs..

It may be feasible to utilise ground bearing floor slabs on top of the engineered fill however the advice of a specialist ground improvement contractor should be sought to confirm the suitability of this scheme and that total settlements can be limited to acceptable levels.

5.3 Roads and Pavements

Thirteen CBR plate load tests were completed at 0.4m bgl within the shallow Raised Marine Deposits across the Site using a 600mm diameter plate. The location of the CBR tests are included as Figure 2 with logs from each location presented as Appendix C. Copies of the CBR test results are included as Appendix E.

Location	Equivalent CBR by Plate Loading
CBR01	7.9 %
CBR02	5.1 %
CBR03	3.0 %
CBR04	2.0 %
CBR05	7.3 %
CBR06	2.9 %
CBR07	FAIL - Test Terminated due to soft ground unable to support Kentledge test
CBR08	2.6 %
CBR09	4.3 %
CBR10	2.5%
CBR11	2.3 %
CBR12	4.4 %
CBR13	1.3 %

Based on the findings of the ground investigation, generally very low values locally <2.5% have been recorded across the main development and it will be necessary to consider the use of modification techniques such as the use of lime and geotextiles/ geomembranes to improve the workability of the surface materials prior to the construction of roads.

Further consideration should be given to the implications of undertaking construction works during wet weather periods and haul roads will need to be constructed using low fine content granular materials to allow a safe working platform to traverse the Site. Due to the potential for intermixing, the materials will likely need to be underlain by geotextile membrane to minimise the potential of contaminating the overlying granular materials. It is recommended that plate CBR tests are undertaken at formation level following stabilisation of the imported material.

Higher CBR values at CBR01 and CBR05 were located in an area of the Site that has been noted as higher than the surrounding land areas located next to the existing access track. Ground conditions in these areas were noted to be drier during the investigation whereas the locations of the remaining CBR tests were undertaken in an area of the Site where standing water and shallow groundwater has been identified in periods of inclement weather and winter months.

Due to the proposed land raising and potential for saturated soils in these areas it is recommended that these soils may require stabilisation to improve the characteristics of the Soil. Equally on the basis that some differential settlement and movement may occur across external areas it is recommended that a geotextile layer be incorporated into the subbase to reduce subgrade thicknesses and to accommodate differential settlements.

It is recommended that a specialist geotextile consultant be consulted to confirm the design and suitability of a system to reduce subgrade thicknesses and differential settlements across the Site.

Where engineered fill is to be placed across external areas it is recommended that the material be placed to provide a minimum CBR performance of 5%.

5.4 Drainage and Soakage Tests

Infiltration testing was carried out at two locations (SA01 and SA02) on 13th April 2021. Water at both locations failed to discharge to less than 25% of the original starting level over a 24-hour period and are considered to have effectively failed in accordance with BRE365 guidance. Results are presented in Appendix I and are summarised in the table below.

Exploratory Hole	Response Stratum	Permeability (m/s)
SA01	Raised Marine Deposits	Failed
SA02	Raised Marine Deposits	Failed

5.5 Excavations & Obstructions

It is expected that conventional mechanical excavators will readily remove the Topsoil, Raised Marine Deposits, River Terrace Deposits, and shallow Chalk likely to be encountered in shallow excavations. Due to the large volumes of material being handled it is likely that large hydraulic excavators will be required.

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.

5.6 Groundwater

Groundwater strikes recorded have been recorded within the Main Development Area from 1.80 to 2.50 m bgl (-0.92m AOD) within the Raised Marine Deposits and 3.00 to 9.50 m bgl (-1.97 to -8.63m AOD) within the Undifferentiated Chalk Formation. Additionally, within the Flood Compensation Area groundwater strikes were encountered between 2.70 to 3.00 m bgl (-0.23 to 0.25 m AOD) within the Undifferentiated Chalk Formation.

Groundwater levels have been monitored in the Raised Marine Deposits between 0.25 and 1.88m bgl (-0.05 – 0.71m AOD) and within the Undifferentiated Chalk between 0.51 and 1.89m bgl (-0.86 to 0.56m AOD), and broadly equilibrate indicating that groundwater within the Undifferentiated Chalk is sub artesian in nature.

Additionally, groundwater levels within the Raised Marine Deposits were monitored by Hydrock as part of a winter monitoring programme where groundwater levels ranged between 0.00 and 2.34 m bgl (-0.43 – 1.26 m AOD).

It is noted that depth to groundwater levels has increased slightly during drier months indicating a degree of seasonality, as indicated by the increase in depth to groundwater encountered in winter months by Hydrock and during Delta-Simons monitoring undertaken in the spring and summer months. Additionally, it is recognised that groundwater levels can vary following weather events. Results of Delta-Simons continuous monitoring has indicated that ground water levels fluctuated between 0.69 and 1.43 m bgl (0.03 and 0.33 m AOD) and notable patterns of decreasing depth to groundwater were identified following significant rain events, when compared to Met Office rainfall data. During reconnaissance visits to the Site during February 2021, standing water was noted to be widespread across the Main Development Area, indicating that groundwater during winter months is extremely shallow.

Based on Site observations during the winter period and subsequent groundwater monitoring during winter/spring period 2020/2021, excavations are likely to be prone to inundation and catastrophic flooding which may prevent the completion of cut exercise and potentially result in damage of soils which are proposed for reuse at the Site. Shallow groundwater/ flooding of areas to be raised may physically prevent earthworks related activities from occurring at the Site.

Of specific note where infrastructure excavations are taken into and below the existing surface level then they may require shoring and specialist dewatering using dedicated dewatering system to locally reduce groundwater levels and permit the safe entry into excavations may be required.

Due to the shallow and open nature of excavations, significant volumes of water will likely be generated and due to the levels of disturbance and colour will likely require specialist treatment via silt treatment and sedimentation systems prior to discharge to surface water. Where water cannot be discharge to surface water features then large storage features may be required to permit the controlled release of surface water into the drainage network.

5.7 Slopes & Retaining Features

This assessment has not assessed the relationship with the proposed land raising activities on Site within the Main Development Area and the adjacent railway located adjacent to the east of the Site. It may be necessary to demonstrate that the proposed development will not have a detrimental impact upon the stability of the soils supporting the existing railway embankment and depending on the requirements, a global slope stability assessment may be requested. It is recommended that contact with Network Rail should be made at the earliest opportunity to further assess the Sites development and potential effects on Network Rail infrastructure.

5.8 Earthworks

5.8.1 General Earthworks

It is understood that a significant programme of earthworks will be undertaken at the Site, taking place over the Main Development and the Flood Compensation Areas.

Due to the Site's location within a flood zone it has been deemed necessary to raise Site levels by approximately 2m resulting in the requirement to import 85,700m³ of material. It will also be necessary to provide a Flood Compensation Area (FCA) to allow for excess water to drain away from the existing development into adjacent fields during flood events. Based on initial calculations, the FCA will need to be constructed to a minimum depth of 0.9m AOD resulting in the generation of ~122,169m³ of material of which a proportion (sands and clay) have been designated for reuse as engineered fill. Due to insufficient material being available for use as engineered fill, further excavation of materials to the north of the FCA has been proposed to provide the outstanding volume of material required for use as engineered fill. Drawing 2 indicates final formation levels for the warehouse to be 3.65m AOD.

Due to the poor performance of the underlying Raised Marine Deposits it is envisaged that the underlying soils will be subject to a degree of compression due to the imposition of a uniformly distributed load by the placement of a 2m thick platform of engineered fill.

In order to assess indicative settlements, two models utilising different imposed loads, equating to different material thickness have been assessed using P-Disp modelling software:

- ✦ For a load of 40kpa (to represent 2m fill) up to 46.7mm of settlement was predicted
- ✦ For a load of 55kpa load there is up to 78.4mm of settlement predicted

These settlements are unlikely to be acceptable and may result in significant differential settlement between dock loaders and structures, but also external areas. It is also likely that remedial works to external areas would be required due to ongoing settlement.

On this basis it may be necessary to consider the use of ground improvement techniques to improve the performance of the soils to minimise total settlements following the placement of engineered fill. Depending on the end performance requirements of the material to be placed as engineered fill there are two sequencing options that could be adopted comprising the following:

- ✦ Stabilisation of formation prior to raising site levels with compacted engineered fill.
- ✦ Raising site levels with fill followed by subsequent stabilisation using a range of techniques.

The preferred sequence would need to be considered by the Principal Contractor and based on advice provided by specialist ground improvement contractors. The first technique would provide the benefit of a formation which could directly be built off with controlled engineered fill however this would potentially result in delays to material movements due to the requirement to construct a piling mat for ground improvement techniques.

The latter technique would enable a more rapid movement of materials to be accumulated within the Main Development Area and allow for techniques such as surcharging to commence however the resulting thickness

of fill and deeper Raised Marine Deposit material may result in higher treatment costs. Raised material would also not be subject to the same degree of compaction as per the first technique to avoid duplication of effort and to ensure that improvement techniques can effectively penetrate the controlled engineered fill which may result in groundwater ingress and deterioration of materials whilst they are awaiting improvement and capping.

Techniques that could be used for improving ground conditions are likely to comprise either vibro concrete columns or a similar method or the use of a rolling surcharge.

Conversations with contractors with specialist vibro ground improvement techniques have indicated that the former technique may be suitable subject to detailed review of the proposed loading regime and ground conditions whilst the latter technique would also require further detailed review and design to establish timeframes to undertake sufficient improvement of the ground to permit the use of the technique and to establish the economic viability to install sufficient wicking drains to reduce timeframes to an acceptable level. At this stage, the duration of any rolling surcharge would be dependent on the consolidation of the materials and is likely to be measured in the order of months with further detailed analysis required to establish a cost benefit to assess the effectiveness in constructing additional band drains and corresponding reduction in surcharging timeframes.

5.8.2 Earthworks Material

Based the proposed cut and fill model it is understood that materials won from the FCA and FEA are likely to comprise, topsoil, clay from the River Terrace Deposits and structureless chalk from the undifferentiated chalk strata. As part of the ground investigation Delta Simons have collected multiple samples from this area which have been subject to a series of earthworks classification tests which have resulted in the following earthworks classifications based on the Highways Authority Specification for Highways Works Series 600 (HASWH600).

Location	Depth (m)	Strata	Specification for Highways Earthworks Classification
TP201	1.0 - 1.20	River Terrace Deposits	Class 2A/B Wet Cohesive Fill
TP205	1.0 - 1.20		Class 2A/B Wet Cohesive Fill
TP209	2.0		Class 2A/B Wet Cohesive Fill
TP209	1		Class 2A/B Wet Cohesive Fill
TP211	1.0 - 1.20		Class 2A/B Wet Cohesive Fill
TP211	3.0		Class 2A/B Wet Cohesive Fill
TP212	1.0 - 1.20		Class 2A/B Wet Cohesive Fill
TP217	1.0 - 1.20		Class 2A/B Wet Cohesive Fill
TP218	3.0		Class 3 General Fill Chalk
TP218	1.0		Class 2A/B Wet Cohesive Fill
TP217 - TP201	1.0 - 3.0		Class 2A/B Wet Cohesive Fill
TP219 - TP203	1.0 - 2.20		Class 2A/B Wet Cohesive Fill
TP220 - TP206	1.0 - 2.20		Class 2A/B Wet Cohesive Fill
TP214 - TP210	1.0 - 3.0		Class 3 General Fill Chalk
TP211 - TP207	1.0 - 2.20		Class 2A/B Wet Cohesive Fill
TP209	3.0		Class 2A/B Wet Cohesive Fill
TP205	2.0 - 2.20	Undifferentiated Chalk	Class 3 General Fill Chalk
TP205 - TP206	2.90 - 3.0		Class 3 General Fill Chalk
TP219 - TP204	2.0 - 2.20		Class 3 General Fill Chalk
TP201	1.0 - 1.20		Class 3 General Fill Chalk

Materials used as fill will need to be placed to a suitable engineering specification with the degree of compaction required dependent on end usage and serviceability criteria.

As part of the earthwork's classification testing, site won materials were subject to compaction tests (Maximum Dry Density/ Optimum Moisture Content tests) using a 2.5kg rammer. The results of the test are presented below.

Location	Depth m bgl	Strata	As received Moisture Content %	Optimum moisture content %	Maximum Dry Density	Comment
TP201	1.0 -1.20		18	18	1.75	
TP205	1.0 -1.20		23	16	1.71	Wet of optimum and likely to be outside of 95% MDD
TP209	1.0		21	16	1.75	Wet of optimum – as received material within 95% of MDD
TP212	1.0 -1.20		20	16	1.76	Wet of optimum as received material within 95% of MDD
TP216	2.90		19	16	1.78	Wet of optimum as received material within 95% of MDD
TP218	1.0		22	15	1.78	Wet of optimum likely to be within 95% of MDD
TP218	3.0		17	16	1.80	
TP211 - TP207	1.0 - 2.2		17	16	1.8	
TP214 - TP210	1.0 - 3.0		19	13	1.84	Wet of optimum and likely to be outside of 95% MDD
TP217 - TP201	1.0 - 3.0		19	16	1.78	Wet of optimum as received material within 95% of MDD
TP219 - TP203	1.0 - 2.20		20	14	1.86	Wet of optimum and likely to be outside of 95% MDD
TP220 - TP206	1.0 - 2.20		17	17	1.72	

TP205	2.0 - 2.2	Undifferentiated Chalk	21	20	1.67	Wet of optimum as received material within 95% of MDD
TP204	2.90 - 3.0		23	23	1.67	
TP209	3.0		19	21	1.72	
TP205 - TP206	2.90 - 3.0		19	22	1.66	moisture addition required to achieve OMC and to achieve 95%MDD
TP219 - TP204	2.0 - 2.20		23	20	1.73	Wet of optimum as received material within 95% of MDD

The above table indicates that the River Terrace Deposits and undifferentiated Chalk Deposits within the Flood Compensation Area are typically wet of optimum, with greater variances in the former recorded. It should however be noted that the majority of samples were found to have their dry density within 95% of the maximum dry density and therefore with the exception of one sample from the River Terrace deposits, no further treatment to achieve 95% compaction density may be required. It should also be noted that one sample from the chalk strata was found to be dry of optimum and likely to require the addition of water to achieve 95% of the maximum dry density.

Based on the presence of shallow groundwater, some degree of moisture control was anticipated and the client requested that additional lime testing be undertaken assess the benefit and likely cost implication to reduce moisture contents to acceptable levels during the working of materials. On this basis, the geotechnical laboratories mixed batches of soil with varying proportions of lime (0.5%, 1% and 2%) to assess the impact and likely future requirements for the proposed development scheme.

A summary of the results for a variety of lime dosages is presented overleaf.

Location	Depth m bgl	Strata	As received Moisture Content %	Optimum moisture content %	Maximum Dry Density	Moisture Content 0.5 % Lime Added	Moisture Content 1 % Lime Added	Moisture Content 2% Lime added	Comment
TP216	2.90	River Terrace Deposits	19	16	1.78		13		DD within 95% of MDD
TP217 - TP201	1.0 - 3.0		19	16	1.78	12	12	8.7	Addition of 0.5 % lime reduces moisture content to below OMC but within 9% of MDD. Changes to MDD noted for 8.7%
TP219 - TP203	1.0 - 2.20		20	14	1.86	12	9.5	8.4	Addition of 0.5 % lime reduces moisture content to below OMC. MDD >100% and increases with lime addition
TP220 - TP206	1.0 - 2.20		17	17	1.72	13	12	11	Addition of 0.5 % lime reduces moisture content to below OMC MDD >100% and increases with lime addition
TP214 - TP210	1.0 - 3.0		19	13	1.84	8.9	8	7.2	Addition of 0.5 % lime reduces moisture content to below OMC MDD >100% and increases with lime addition
TP211 - TP207	1.0 - 2.20		17	16	1.8	12	9.9	6.3	Addition of 0.5 % lime reduces moisture content to below OMC MDD >100% and increases with lime addition
TP205 - TP206	2.90 - 3.0	Undifferentiated Chalk Formation	19	22	1.66	17	16	11	Addition of 0.5 % lime reduces moisture content to below OMC MDD >100% and increases with lime addition
TP219 - TP204	2.0 - 2.20		23	20	1.73	15	14	13	Addition of 0.5 % lime reduces moisture content to below OMC MDD >100% and increases with lime addition

The results of the lime dosage trials indicating maximum dry densities to rapidly increase with the addition of lime. Most noticeably, low dosage levels of lime resulting in significant moisture content variations such that soils can move from slightly low to slightly high of optimum within minimal additions of lime. It is recommended that a specialist ground contractor review the information provided and satisfy themselves regarding the requirements for stabilisation given current and likely future working conditions.

As part of the lime dosage trials, hand shear vane tests were completed at each compaction point with a summary of the results presented below.

Location	Depth m bgl	Strata		Moisture Content %															
				<13	14	15	16	17	18	19	20	21	22	23	24	25	27	28	
TP201	1.0 – 1.20	River Terrace Deposits	HSV – Average Shear Strength kPa			UTP	UTP		89			61			26				
TP205	1.0 – 2.0			UTP	UTP		120			66		67							
TP209	1.00			UTP	UTP	129			98			63							
TP212	1.0 – 2.0			UTP			150				70		22						
TP216	2.90			UTP	UTP		109			77	32								
TP218	1.00			UTP		UTP			89			64							
TP218	3.00			UTP		101			61		38								
TP217 – TP201	1.0 – 3.0			UTP	134		92			51			23						
TP219 – TP203	1.0 – 2.20			UTP	UTP	UTP			52			32							
TP220 – TP206	1.0-2.20			UTP		UTP		138		95			28						
TP214 – TP210	1.0 – 3.0	UTP				110		37											
TP211 – TP207	1.0 – 2.20	UTP		UTP	UTP		80		38										
TP204	2.90 – 3.00	Undifferentiated Chalk Formation						UTP			83		36		8		4		
TP205	2.0 – 2.20			UTP		UTP		134		29		105							
TP209	3.00						UTP			UTP		26		11		6			
TP205 – TP206	2.90 – 3.0								UTP		UTP		51		11		43		
TP219 – TP214	2.0 – 2.20						UTP			UTP	110			84		63			

*UTP = unable to penetrate

The results of the testing generally indicated that where soils were dried below their optimum moisture content it was not possible to undertake hand shear vane tests due to the non-plastic behaviour of the material. Moisture contents at and marginally below the optimum moisture content were found to exhibit maximum shear strengths with shear values typically corresponding to stiff clay however significant reductions in shear strength reducing from stiff to soft were noted in several samples corresponding to only several percentage moisture variations. It should therefore be noted that the performance of the soils are highly susceptible to moisture content.

To supplement the Hand Shear Vane tests carried out on the samples indicated in the table above. Subsequent tests on combined samples were repeated with varying quantities of lime to assess any variability in shear strength. The above pattern was noted to be less obvious in lime stabilised soils which may result in part from lime reacting with the material itself resulting in increased geotechnical performance of the material.

Location	Depth m bgl	Strata	HSV – Average Shear Strength kPa	Moisture Content %															
				< 11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
TP211 – TP207 0.5% lime added	1.0 – 3.0	River Terrace Deposits			UTP		150		51		33								
TP211– TP2207 1% lime added	1.0 – 3.0			UTP	150	73		73		28			21						
TP211 – TP207 2% lime added	1.0 – 2.20			UTP			150			94									
TP214 – TP210 0.5% lime added	1.0 – 3.0			UTP		UTP				123	82								
TP214 – TP210 1% lime added	1.0 – 3.0				UTP		150			107									
TP214 – TP210 2% lime added	1.0 – 3.0			UTP		150	133												
TP217 – TP201 0.5% lime added	1.0 – 3.0				UTP			150	120			85		58					
TP217 – TP201 1% lime added	1.0 – 3.0				UTP	UTP		150		114		62							
TP217 – TP201 2% lime added	1.0 – 3.0				150		122			96									
TP219 – TP203 0.5% lime added	1.0 – 2.20					UTP	UTP	110			84		50						
TP219 – TP203 1% lime added	1.0 – 2.20					UTP	133			105		84							
TP219 – TP203 2% lime added	1.0 – 2.20					UTP		150		133									
TP220 – TP206 0.5 % lime added	1.0-2.20						UTP	UTP			150		106	47					
TP220 – TP206 1% lime added	1.0-2.20					UTP		UTP		150			150						
TP220 – TP206 2% lime added	1.0-2.20						UTP		UTP			150		135					
TP205 – TP206 0.5% lime added	2.90 – 3.0	Undifferentiated Chalk Formation							UTP			UTP	91		18		45		
TP205 – TP206 1% lime added	2.90 – 3.0							UTP	UTP			98		64	29				
TP205 – TP206 2% lime added	2.90 – 3.0			UTP			UTP		UTP		150			99					
TP219 – TP214 0.5% lime added	2.0 – 2.20						UTP		UTP		136		121		88				
TP219 – TP214 1% lime added	2.0 – 2.20						UTP		UTP		UTP		138		123				
TP219 – TP214 2% lime added	2.0 – 2.20						UTP	UTP			UTP	150			132				

*UTP = unable to penetrate

The preliminary suitability of earthworks materials has been assessed on the basis of the testing carried out as part of this investigation. The materials encountered on Site may vary slightly from those analysed; furthermore, inclement weather or winter working may result in materials being unsuitable for incorporation within the works without modification by lime, cement or other methods. In particular, cohesive soils, encountered at the Site, are very susceptible to 'wet weathering working' With the results of shear strength testing indicating performance of the soils to be highly dependent on moisture content.

Consideration will need to be given to the performance of the soils over the long term and the sensitivity of the land use, where greater flexibility and tolerances are applicable then it may be feasible to utilise a less onerous method of compaction to place the material, however, in areas of greater sensitivity then a greater method of compaction may be required.

The assessment has identified that soils are likely to be highly susceptible to moisture variation and as part of the earthworks the contractor will need to make an allowance and provide a methodology for wet weather working and stabilisation of materials that have become unsuitable for use either during the generation of the material and or as part of the daily placement of materials (site scrape).

Specifically, the contractor will need to ensure that following placement of engineered materials, that they are suitably capped and protected and allowed to be free draining to prevent the accumulation of water and softening of the formation. Drainage ditches and methods to control surface water will need to be implemented as part of the construction build up.

Due to the Main Development being located within an area considered susceptible to flooding and shallow groundwater, where earthworks are undertaken during periods of inclement weather an allowance should be made for an alternative build up layer with either geotextile membrane and/or oversize granular layers being placed down to permit the placement of engineered fill. Site won engineered fill should not be placed within saturated or flooded areas and alternative media or cessation of works may need to occur.

Further earthworks testing will be required prior to completion of a suitably detailed earthworks specification for the works. Depending on the nature of any treatment that is required to the material that is proposed for reuse at the Site, a Materials Management Plan will also be required for the works and should be appropriately signed off by a 'Qualified Person'.

Based on the findings of the ground investigation both the River Terrace Deposits and Undifferentiated Chalk strata are likely to be suitable for use as engineered fill to raise the Main Development Area. It should be noted that chalk deposits are likely to be more sensitive to moisture content variation and can be prone to rapid deterioration in their physical characteristics especially during excavation and placement. Given that chalk deposits will most likely be encountered at the base of the excavation, close to the water table it is likely that these materials may become unsuitable for use as engineered fill during winter periods and where feasible it is recommended that these materials are not utilised until dry weather and water levels have reduced to a suitable level.

Based on the groundwater level monitoring undertaken within the Main Development Area, groundwater is broadly noted to be below 0.m AOD between December and March, however, water levels are likely to fluctuate between significant groundwater monitoring events. It should be noted that groundwater monitoring has not been undertaken within the FCA and where feasible it is recommended that continuous groundwater monitoring data is collected over a season to monitor these levels to understand worst case scenarios.

Additionally, Organic Matter laboratory testing has indicated that organic matter ranges from 0.3 % - 3% within the River Terrace Deposits, representing a low organic content, in accordance with BS 14688-2:2018- Table 3.

From a material availability perspective, the results of the ground investigation have also identified the River Terrace Deposits to vary across the FCA and subject to further investigation and detailed modelling it may be possible to provide a more detailed earthworks model to maximum the volume of cohesive soils that can be targeted for use as engineered fill.

It should also be noted that significant volumes of topsoil will be generated as a consequence of the site strip and FCA construction, and it may be necessary to find alternative end uses of the material where it cannot be retained on Site.

it is recommended that an earthworks specification be compiled to support the deposition of these materials. With the performance requirements, further compliance and validations testing being dependant on the end use of the materials.

5.9 Chemical Attack on Buried Concrete

5.9.1 Main Development Area

In accordance with the recommendations of BRE Special Digest 1, 'Concrete in Aggressive Ground' 2005, the conditions of the soils within the Site Development Area would therefore be classified as Design Sulphate Class DS-1 and ACEC Class AC-1 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 non-pyritic soils).

5.9.2 Flood Compensation Area.

In accordance with the recommendations of BRE Special Digest 1, 'Concrete in Aggressive Ground' 2005, the conditions of the soils within the Flood Compensation Area would therefore be classified as Design Sulphate Class DS-1 and ACEC AC-1 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 non pyritic soils - no groundwater data available).

5.10 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 I utilising data from Delt-Simons and Hydrock' investigation and identifies geotechnical hazards/risks associated with the construction phase. The following Substantial Risks have been identified:

- ▴ Compressible Soils
- ▴ High Groundwater Table
- ▴ Suitability for re-use of materials from the FCA
- ▴ Structural damage to the adjacent railway line.

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.

As part of this assessment, soil chemical analysis results from Main Development Area, Flood Compensation Area and Delta-Simons' previous investigation have been included allowing for a more detailed comparison of potential contaminants at the Site. Additionally, a review of soil chemical analysis from Hydrock's' 2017 report is presented in section 6.2.1.

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 an Industrial end use, considered appropriate based on the proposed industrial development.

6.2.1 Risks from Soil Sources

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

The laboratory results for contaminants exceeding detection limit compared to their respective GAC are presented in the table below.

The primary exposure pathways considered in the risk assessment are as follows:

- ▲ Ingestion of soil and indoor dust and/or oral background exposure.
- ▲ Inhalation of dust (background and indoor).
- ▲ Direct dermal contact; and
- ▲ Inhalation of vapour (background and indoor).

Contaminant	No. Samples	Max Conc. (mg/kg)	GAC (mg/kg)	GAC Source	No. Exceed GAC	Volatile	Location of Exceedances (depth) = Concentration (mg/kg)	Area of Site of Exceedance
Asbestos	23		identification	DS	0	N		
Metals and metalloids								
Arsenic	23	16	640	LQM	0	N		
Cadmium	23	0.5	190	LQM	0	N		
Chromium III	23	35	8600	LQM	0	N		
Chromium VI	23	1.8	33	LQM	0	N		
Copper	23	24	68000	LQM	0	N		
Lead	23	71	2300	C4SL	0	N		
Nickel	23	30	980	LQM	0	N		
Zinc	23	96	730000	LQM	0	N		
Polycyclic Aromatic Hydrocarbons								
Naphthalene	23	0.71	190	LQM	0	Y		
Acenaphthene	23	0.56	84000	LQM	0	Y		
Fluorene	23	1.3	63000	LQM	0	Y		
Phenanthrene	23	8.6	22000	LQM	0	N		
Anthracene	23	3.7	520000	LQM	0	N		
Fluoranthene	23	11	23000	LQM	0	N		
Pyrene	23	8.2	54000	LQM	0	N		
Benzo[a]anthracene	23	3.9	170	LQM	0	N		
Chrysene	23	3.3	350	LQM	0	N		
Benzo[b]fluoranthene	23	4.1	44	LQM	0	N		
Benzo[k]fluoranthene	23	1.9	1200	LQM	0	N		
Benzo[a]pyrene	23	3.4	35	LQM	0	N		
Indeno(1,2,3-c,d)pyrene	23	2.3	500	LQM	0	N		
Dibenzo(a,h)anthracene	23	0.86	3.5	LQM	0	N		

Contaminant	No. Samples	Max Conc. (mg/kg)	GAC (mg/kg)	GAC Source	No. Exceed GAC	Volatile	Location of Exceedances (depth) = Concentration (mg/kg)	Area of Site of Exceedance
Benzo[g,h,i]perylene	23	3	3900	LQM	0	N		
Petroleum Hydrocarbons								
Aliphatic TPH >C10-C12	8	4.3	9700	LQM	0	Y		
Aliphatic TPH >C12-C16	8	2.6	59000	LQM	0	N		
Aliphatic TPH >C16-C21	8	8	1600000	LQM	0	N		
Aliphatic TPH >C21-C35	8	38	1600000	LQM	0	N		
Aliphatic TPH >C35-C44	8	23	1600000	LQM	0	N		
Aromatic TPH >C10-C12	8	18	16000	LQM	0	Y		
Aromatic TPH >C12-C16	8	19	36000	LQM	0	Y		
Aromatic TPH >C16-C21	8	33	28000	LQM	0	N		
Aromatic TPH >C21-C35	8	47	28000	LQM	0	N		
Aromatic TPH >C35-C44	8	45	28000	LQM	0	N		
Total Petroleum Hydrocarbons	8	130	5000	DS	0	Y		
PCB's								
PCB Congener 118	8	0.002	No GAC	No GAC	0	Y		
Other Organic Contamination (Including VOC, SVOC, Herbicides and Pesticide results) all below Limits of Detection								
Notes: Shaded = Maximum concentration exceeds GAC C4SL = Category 4 Screening Levels (C4SLs) published by DEFRA. DS = In-house GAC derived by Delta-Simons Environmental Consultants Ltd, 2018. EIC = Guidance values produced by the Environmental Industries Commission (EIC), the Associated of Geotechnical and Geo-environmental Specialists (AGS) and Contaminated Land: Application in Real Environments (CL: AIRE) in December 2009. LQM = Land Quality Management/CIEH S4UIs for Human Health Risk Assessment, 2014. AGAC = Acute Generic Assessment Criteria published by the Society of Brownfield Risk Assessment (SoBRA) 2019 No GAC = No Generic Assessment Criteria value available for compound.								

None of the site-specific contaminants of concern were recorded at concentrations in excess of their respective GAC, within the Main Development Area or the Flood Compensations Area.

Additionally, according to the Hydrock 2017 report:

“There are no substances for which the US95 exceeds the GAC, for Made Ground and natural soils and it is concluded that no further assessment is required for human health risk”

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 light industrial use, the soil and groundwater chemical data has been compared against a commercial/industrial 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.

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:

- ⚡ No observations of NAPL were made within the soils observed during drilling.
- ⚡ No concentrations of Total Petroleum Hydrocarbons more than 5,000 mg/kg were recorded.
- ⚡ No NAPL was measured during groundwater monitoring works.

On this basis, there is no evidence of NAPL being present on the Site.

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 relevant detection limits are summarised in the table below with a comparison to the GAC applied.

As part of the below contaminative approach, groundwater samples previously collected by Delta-Simons (from boreholes with installations within the Raised Marine Deposits) during an Environmental Due Diligence Investigation have been included.

In addition, groundwater chemical analysis was also undertaken by Hydrock during their 2017 investigation. Results from groundwater within the Raised Marine Deposits have been compared to Delta-Simons commercial screening criteria and has indicated that two out of six samples to exceed generic assessment criteria for sulphate and one out of six samples exceeding generic assessment criteria for chloride when compared to Water Framework Directive and Drinking Water Standards. Additionally, manganese was found to exceed generic assessment criteria in 5 out of 6 samples tested and copper in all samples tested for The Water Framework Directive. No other exceedances were identified of the adopted screening criteria within the soil leachate and groundwater samples assessed.

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances (depth)	Area of Site of Exceedance
Metals and Metalloids							
Arsenic	11	8.25	50	WFD	0		
Cadmium	11	0.03	0.53	WFD	0		
Chromium III	11	3.6	7.21	WFD	0		
Copper	11	8.7	2.12	WFD	10	CP02 7.6 µg/l CP06 3.8 µg/l BH01 7.5 µg/l BH02 6.1 µg/l BH03 6.7 µg/l BH04 5.9 µg/l BH05 4.7 µg/l BH06 6.7 µg/l BH07 6.2 µg/l BH08 4.8 µg/l	Site Wide
Lead	11	0.3	2.54	WFD	0		
Mercury	11	0.05	0.106	WFD	0		
Nickel	11	12	6.48	WFD	1	CP04 12 µg/l	Centre of the Site
Zinc	11	18	23.1	WFD	0		
Inorganics							
Chloride	3	820000	188000	WFD	1	CP02 820,000 µg/l	South of the Site
Sulphate as SO ₄	11	325000	188000	WFD	5	CP02 325,000 µg/l BH01 281000 µg/l BH02 230000 µg/l BH03 259000 µg/l BH07 275000 µg/l	Site Wide
Notes: Shaded = Maximum concentration exceeds GAC. GAC = No GAC available for individual compounds DWQS 2016 = The Water Supply (Water Quality) Regulations 2016 [UK Drinking Water Standards] WHO 2003 = WHO background documents to Guidelines for Drinking Water Quality, 2003							

Contaminant	No. Samples	Max Conc. (µg/l)	GAC (µg/l)	GAC Source	No. Exceed GAC	Location of Exceedances (depth)	Area of Site of Exceedance
WHO 2003* = The WHO guidance states that the use of the lowest guidance value for aliphatic hydrocarbons (300 µg/l) for comparison to the total TPH concentration in groundwater will provide a conservative level of protection. WHO 2017 = WHO Guidelines for Drinking Water Quality (4 th Edition), 2017.							

Widespread significant groundwater contamination has not been identified at the Site, corroborating with groundwater chemical analysis undertaken by Hydrock.

Localised, elevated concentrations of sulphate, chloride, nickel, and copper were identified within groundwater samples from the Raised Marine Deposits and Undifferentiated Chalk Formation.

Based on the identified exceedances, it is considered that they do not pose a significant risk to nearby surface waters considering that no sources of contamination have been identified on Site. It is likely that concentrations of exceedances are representative of background conditions. It is therefore considered that the exceedances recorded also do not pose a significant risk to controlled waters.

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

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.

A preliminary review of the results indicates that a relevant linkage is unlikely to exist associated with organic contaminants and therefore contaminant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes may be suitable for use on the development.

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.

6.4.2 Building Materials

Risks to building materials associated with aggressive ground conditions is addressed in Section 5.10.

6.5 Waste Classification

This investigation was not undertaken to advise on the classification or potential management routes for waste materials that are likely to be generated during the construction phase of the project. Classification and management of wastes either on to site, off site or within the development are likely to require further investigation and assessment. The extent of such work will depend on the particular management option that is being considered and could, for example, involve the use of waste acceptance criteria analyses.

In accordance with current industry best practice, guidance and legislation Delta Simons would always recommend options including waste treatment and waste recovery be considered ahead of landfill disposal. Landfill disposal should be seen as an option of last resort given that in terms of cost, environment, and social outcomes it is less sustainable.

It should be noted that alternative routes for the use of site won materials is currently being considered within the design team but is outside the remit of this document.

7.0 Bulk Ground Gas Risk Assessment

7.1 Ground Gas Conceptual Site Model

7.1.1 Sources

The Site has historically been used for agricultural purposes, with limited area of made ground identified within the Main Development Area and the Flood Compensation Area, however organic soils have been identified within the Raised Marine Deposits that may be a source of gas generation.

7.1.2 Receptors

The principal receptors under consideration are future Site users. Other receptors include adjacent site occupiers and future maintenance/construction workers.

7.1.3 Pathways

The underlying geology identified as the Raised Marine Deposits is considered to be of slight variable permeability with respect to ground gases based on their homogenous nature with small bands of sand identified across the Site which may allow preferential migration locally.

The most significant pathways with respect to future Site users relate to the potential for gases to enter future on Site building. At present, no gas protections measures are assumed. Consequently, ingress into buildings may be possible through voids in the floor including service entry points and cracks.

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.

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 low, whilst the sensitivity of the proposed development is low. On this basis, CIRIA C665 recommends 4 visits over a minimum period of one month.

To date, gas monitoring has been carried out at the Site over three monitoring periods. Initially as part of Hydrock's ground investigation in 2017, four monitoring visits were undertaken over a period of two months between June and July 2017 with monitoring undertaken on six boreholes of which five boreholes were located across the Site development area.

Delta Simons have currently undertaken five rounds of ground gas monitoring between March and July 2021. With three monitoring rounds initially undertaken over a period of four weeks over 14 locations within the proposed warehouse and car park footprints.

A second period of monitoring was undertaken following the installation of boreholes during the most recent round of investigation with one round of monitoring undertaken to date over 17 locations covering the proposed building footprints and Site wide.

During the Delta-Simons monitoring Barometric pressures during the gas monitoring period ranged from 1030 mBar to 1000 mBar, with two out of five visits completed during periods of falling pressure.

7.3 Ground Gas Risk Assessment

7.3.1 Background

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

- ▲ 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 Gas Screening Value (GSV)

The Gas Screening Value (gas concentration as a fraction x maximum recorded flow) 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.

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)
				Methane		Carbon Dioxide		
				GSV	CS	GSV	CS	
VP01	<0.1	<0.1	<0.1	0.0001	1	0.0001	1	No
VP02	0.3	0.3	<0.1	0.0003	1	0.0003	1	Yes (round 1,2)
VP03	0.2	0.7	0.4	0.0008	1	0.0028	1	No
VP04	0.2	1.2	<0.1	0.0002	1	0.0012	1	No
VP05	0.2	0.6	<0.1	0.0002	1	0.0006	1	Yes (round 1, 2)
VP06	0.2	0.3	<0.1	0.0002	1	0.0003	1	Yes (round 1)
BH01S	0.2	2.8	<0.1	0.0002	1	0.0028	1	No
BH01D	<0.1	2.3	<0.1	0.0001	1	0.0023	1	No
BH02S	0.2	1.3	<0.1	0.0002	1	0.0013	1	Yes (round 2,3,4)
BH02D	<0.1	0.5	<0.1	0.0001	1	0.0005	1	Yes (round 2,3,4,5)
BH03S	0.2	0.4	<0.1	0.0002	1	0.0004	1	Yes (round 2,3,4,5)
BH03D	<0.1	0.1	<0.1	0.0001	1	0.0001	1	Yes ,2,3,4,5
BH04S	0.2	3.8	<0.1	0.0002	1	0.0038	1	No
BH04D	<0.1	0.1	<0.1	0.0001	1	0.0001	1	Yes (round 2,3,4,5)
BH05S	0.2	0.5	<0.1	0.0002	1	0.0005	1	No
BH06S	0.2	<0.1	<0.1	0.0002	1	0.0001	1	Yes (round 2,3,4,5)
BH07S	0.2	0.2	<0.1	0.0002	1	0.0002	1	No
BH08S	0.2	3.3	3	0.006	1	0.099	2	Yes (round 2,3,4,5)
CP06	<0.1	0.2	<0.1	0.0001	1	0.0002	1	Yes (round 4,5)
CP04	<0.1	<0.1	<0.1	0.0001	1	0.0001	1	Yes (round 4,5)
CP03	<0.1	<0.1	<0.1	0.0001	1	0.0001	1	Yes (round 4,5)
CP02	<0.1	0.3	<0.1	0.0001	1	0.0003	1	Yes (round 4,5)

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)
				Methane		Carbon Dioxide		
				GSV	CS	GSV	CS	
BH04HY	<0.1	0.1	<0.1	0.0001	1	0.0001	1	Yes (round 4,5)
BH03HY	<0.1	2.2	<0.1	0.0001	1	0.0022	1	Yes (round 4,5)
BH05HY	<0.1	0.4	<0.1	0.0001	1	0.0004	1	Yes (round 4,5)
Notes: 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.								

The preliminary data indicates that the Site can be provisionally classified as CS1 (very low hazard potential) in accordance with BS 8485:2015 Table 2. A flow rate of 3 (l/hr) was recorded on the final round of monitoring at BH08S indicating a characteristic situation 2 designation for this location. However based on the borehole being flooded consistently during monitoring and the single occurrence of elevated flow rate at this location, it is therefore considered to be attributed to the piston effect where flow rates are artificially elevated due to increased pressure within the borehole by caused by the movement of water within the borehole.

It is therefore considered that the site can be classified as CS1 in accordance with BS 8485:2015 Table 2.

7.4 Ground Gas Risk Mitigation

The ground gas regime at the site has been classified as CS1 for design purposes, and as such ground gas protection measure are not deemed necessary for the development.

7.5 Radon

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

7.6 Organic Vapours

No sources of volatile vapours have 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 intrusive investigation, suitable for a Site with a commercial end use.

Revised Conceptual Site Model				
Source	Pathways	Receptors	Confirmed Risk?	Mitigation
Limited Made Ground identified within the Main Development Area and Flood Compensation Area	Ingestion and/or inhalation of soil/dust	Human health – future Site Users	No	Elevated concentrations of contamination above assessment criteria suitable for a commercial development have not been identified at the Site within soils or shallow groundwater.
	Migration of ground gas / vapours into on-site buildings	Human health – construction workers	No	Should unanticipated contamination be identified during the course of enabling works it is recommended that a hotspot protocol be followed. A copy of a suitable hotspot protocol is included as Appendix L. Additionally, results of ground gas monitoring have indicated the Site to be classified as CS1 and as such no specific gas protection measures are considered necessary within the development however a watching brief should be maintained throughout the works for unanticipated contamination.
	Migration of contaminants into groundwater	Secondary A (Raised Marine Deposits) and Principal Aquifer (Undifferentiated Chalk Formation) Aquifers	No	
	Migration of contaminants into surface waters	Lidsey Rife		
Elevated Sulphate, Chloride, Nickel and Copper within Groundwater	Migration of Contaminants into groundwater and surface waters	Secondary A aquifer (Raised Marine Deposits) and Principal Aquifer (Undifferentiated Chalk Formation) Surface waters: Lydsey Rife	No	Elevated concentrations of sulphate, copper and chloride were identified above Generic Assessment Criteria within groundwater from the Undifferentiated Chalk Formation. Additionally, elevated concentrations of copper and sulphate were identified above GACs in groundwater from the Raised Marine Deposits. These exceedances are however deemed to be representative of the wider groundwater quality and as such represent a low risk to controlled waters and surface waters.

9.0 Conclusions & Recommendations

Development at the Site is proposed to comprise the construction of a warehouse with offices and ancillary structures and parking, an additional multi-storey car park is also proposed to be constructed at the Site. The Site is however located within a flood zone and there is a requirement to raise site levels by approximately 2m and create a flood compensation zone to the north of the Site.

Site levels will be raised by utilising excavated materials from the flood compensation zone to the north. It is proposed to utilise 85,700 m³ of materials from the flood compensation area and an additional area known as the fill extraction area.

9.1 Geotechnical Summary

The Site has undergone several phases of ground investigation, with ground conditions within the Main Development Area generally found to comprise a sequence of topsoil to depths of 0.70 m bgl followed by Raised Marine Deposits comprising gravelly, sandy clay to depths of 6.0 m bgl which in turn was found to be underlain by the Undifferentiated Chalk Formation, comprised of structureless chalk which was recovered as white silty gravel to depths of >35 m bgl

Ground conditions within the FCA/FEA were found to comprise a sequence of topsoil to depths of 0.50 m bgl followed by River Terrace deposits comprising gravelly silty clay to depths of >3.0 m bgl. A limited area of Made Ground was identified where traces of red brick were identified within the topsoil. deposits of the Undifferentiated Chalk Formation was found underlying the River Terrace Deposits and was comprised of structureless chalk recovered as white silty gravel.

The ground investigations undertaken to date have identified poor ground conditions across the Site development area, with the Raised Marine Deposits exhibiting low shear strengths and N60 values across the Site.

Due to the expected design loads to be imposed at the Site, the development is likely to be prone to excessive and differential settlement. A piled foundation solution with fully suspended floor slab transferring loads into the competent Undifferentiated Chalk Formation is recommended for the warehouse and car park structures across the Site.

Where a ground bearing floor slab is considered desirable then further detailed modelling and consultation with specialist ground improvement contractors should be undertaken to assess the viability of this technique.

Due to the raising of ground levels, external areas of the Site are likely to be prone to excessive and differential settlement, and it is likely that a range of ground improvement techniques such as vibro concrete columns will need to be adopted prior to land raising or alternatively surcharging techniques could be utilised however timeframes associated with the latter are likely to preclude the use of this technique.

It should be noted that external areas such as dock loaders and yards that are sensitive to differential settlements and where ground improvement techniques are unable to provide sufficient settlement tolerances these may also need to be piled. Delta-Simons have undertaken a series of earthworks classification across the Site to ascertain the suitability of materials which has indicated that Site won materials from the River Terrace deposits are likely to be classified as Class 2A/2B, whilst chalk materials are likely to be classified as Class 3 Engineered Fill in accordance with HASHW600.

The results of the geotechnical testing indicated that materials were generally slightly wet of optimum but following compaction would likely be within 95% of their maximum dry density. The testing also demonstrated that materials were prone to significant sensitivity to moisture content variation and where exposed to inclement weather could rapidly deteriorate which may need result in the requirement for the addition of moisture reducing agents, details of lime dosage trials are included within the report.

Groundwater levels have been monitored in the Raised Marine Deposits between 0.25 and 1.88m bgl (-0.05 – 0.71m AOD) and within the Undifferentiated Chalk between 0.51 and 1.89m bgl (-0.86 to 0.56m AOD), and is likely to display seasonal variations and depth to groundwater is likely to decrease in winter months.

Based on investigations, soils within the Main Development Area and the Flood Compensation Area can be classified as DS-1 and ACEC Class AC-1 for soils and groundwater when considering the most appropriate type of concrete to be used at the Site.

Generally low CBR values have been recorded across the Site locally <2.5% and hence some degree of stabilisation and the use of geotextile membranes may be required as part of the road build up. Due to the significant earthworks that will take place at the Site raising Site levels by approximately 2 m, it is recommended that plate CBR tests are undertaken at formation level following stabilisation of the imported material.

It was noted that higher CBR values were recorded in areas of the Site that were 'Dry' indicating that moisture and groundwater levels have an impact on CBR values. In external areas away from land raised areas it is recommended that these soils may require stabilisation and the inclusion of a geotextile layer incorporated into the subbase to accommodate differential settlements.

9.2 Contamination Issues

9.2.1 Human Health

None of the site-specific contaminants of concern were recorded at concentrations in excess of their respective GAC.

Additionally, ground gas monitoring indicates the Site can be classified as CS1 as such no ground gas protection measures are deemed necessary for the Site.

The future routes of water supply pipes have not been specified to Delta-Simons and it is considered unlikely that upgraded water supply pipes will be necessary. However, as the ground investigation and sampling strategy is not likely to be considered fully compliant with UKWIR recommendations, the potential requirement for upgraded water supply pipes cannot be ruled out.

9.2.2 Controlled Waters

Widespread contamination of groundwater was not encountered during this investigation. Exceedances of sulphate and copper were identified in groundwater within the Raised Marine Deposits and the Undifferentiated Chalk Formation whilst additionally a single exceedance of nickel and chloride was identified within groundwater from the Undifferentiated Chalk Deposits. These exceedances are considered to be representative of background concentrations within the wider groundwater body. Risks to controlled waters and surface waters are considered to be low due to the absence of identified contamination during the investigation and as such no remedial requirements are recommended.

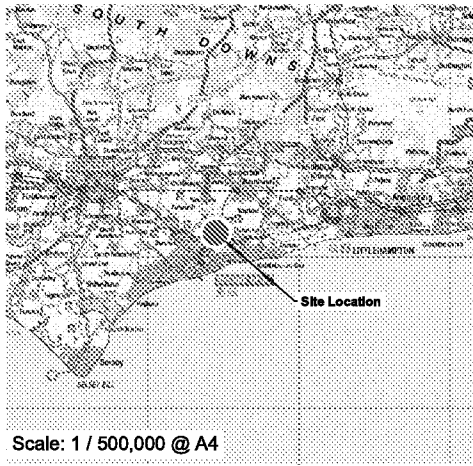
9.3 Recommendations for Supplementary Work

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

- ▲ Preparation of an Earthworks Specification for reuse of soils from the Flood Compensation Area will need to be prepared by a suitably qualified geotechnical engineer to ensure that the materials are placed and compacted to an engineering specification and that the subsequent platform is suitable for development;
- ▲ Earthworks undertaken across the Site may need to be completed under an appropriate Materials Management Plan (MMP) to facilitate the placement of soil materials reused at the Site.
- ▲ It is recommended that specialist contractors confirm the suitability of the proposed foundation solutions, specifically the viability of vibro concrete piles to allow the rapid raising of site levels within Main Development Area.
- ▲ Should earthworks be undertaken during the winter period then earthworks and upfilling activities may become flooded/ inaccessible and require significant stabilisation and treatment of formation levels and materials to be placed as engineered fill;
- ▲ Where time permits, it is recommended that seasonal groundwater monitoring is undertaken in areas to be subject to extraction activities to understand groundwater levels and establish availability of material for use as engineered fill.

- ⚡ Network Rail should be consulted at the earliest opportunity to consult on the effects of the land raising activities on the railway.
- ⚡ CBR tests are undertaken at formation level prior to construction of roads and pavements.
- ⚡ A 'hotspot' protocol should be in place during development works in case unanticipated contamination is encountered; and
- ⚡ This report should be updated following completion of the last round of gas and groundwater monitoring.

Figure 1 – Site Location Map



LEGEND

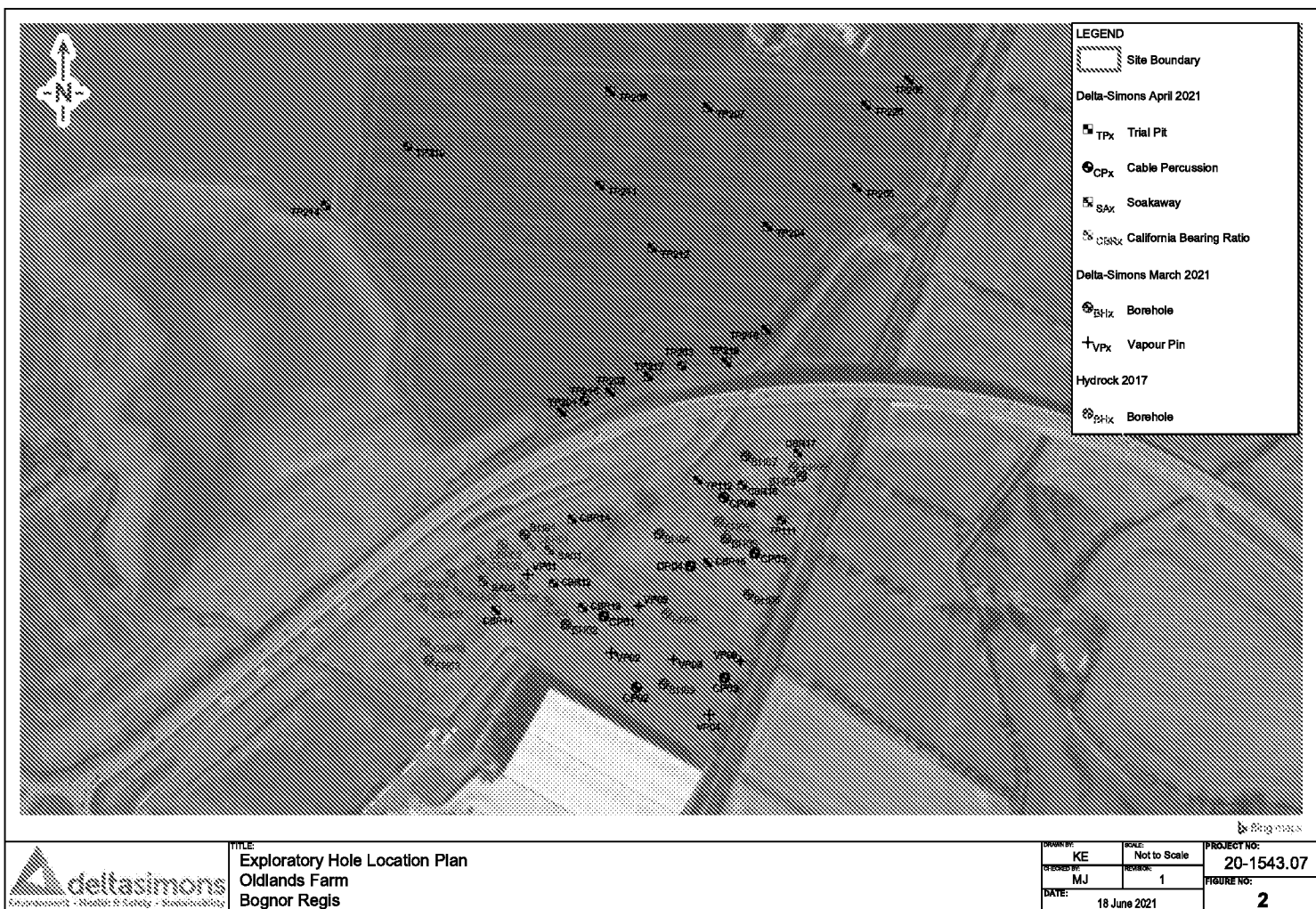
 Site Boundary



Scale: 1 / 10,000 @ A4

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Figure 2 – Exploratory Hole Location Plan



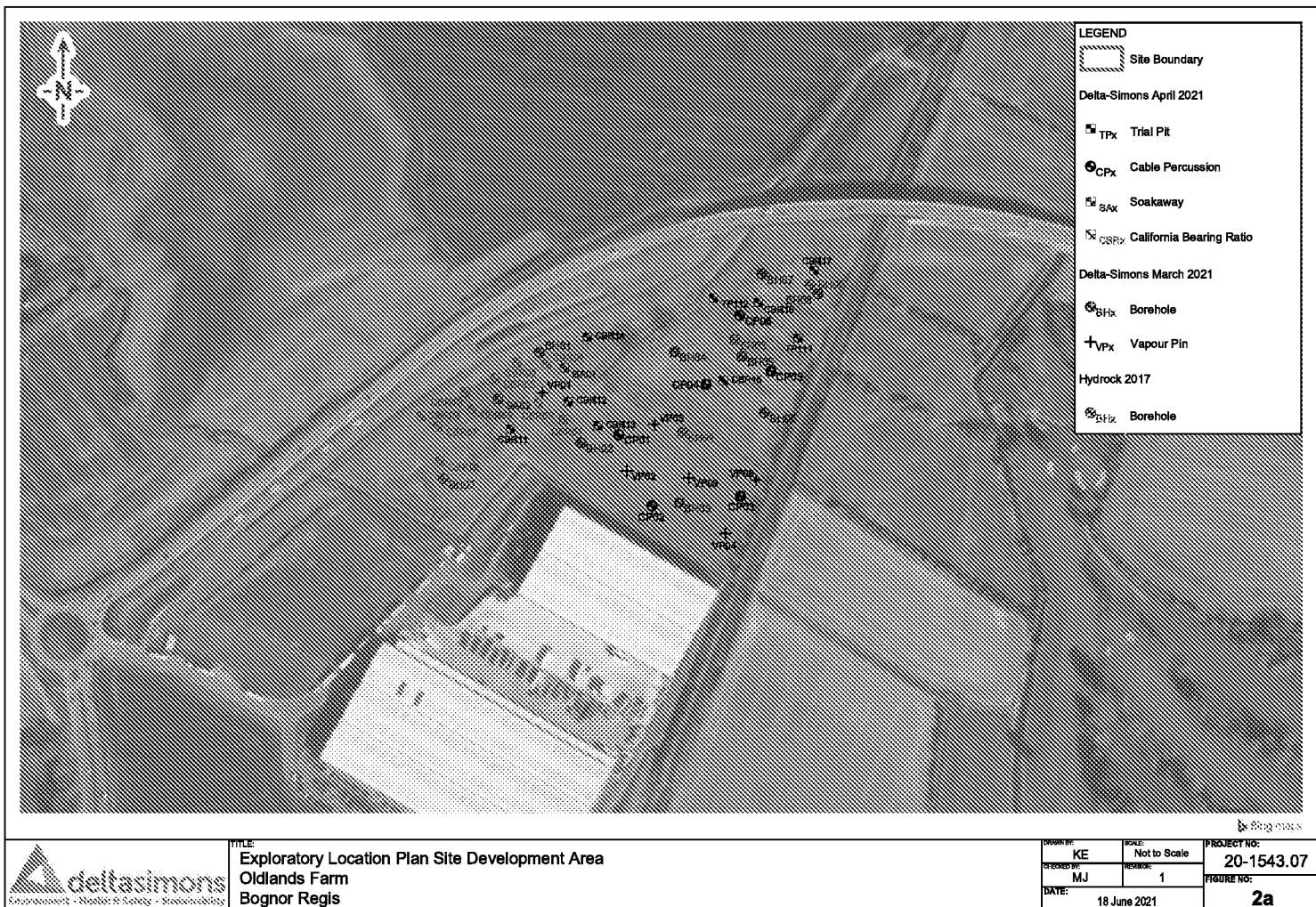
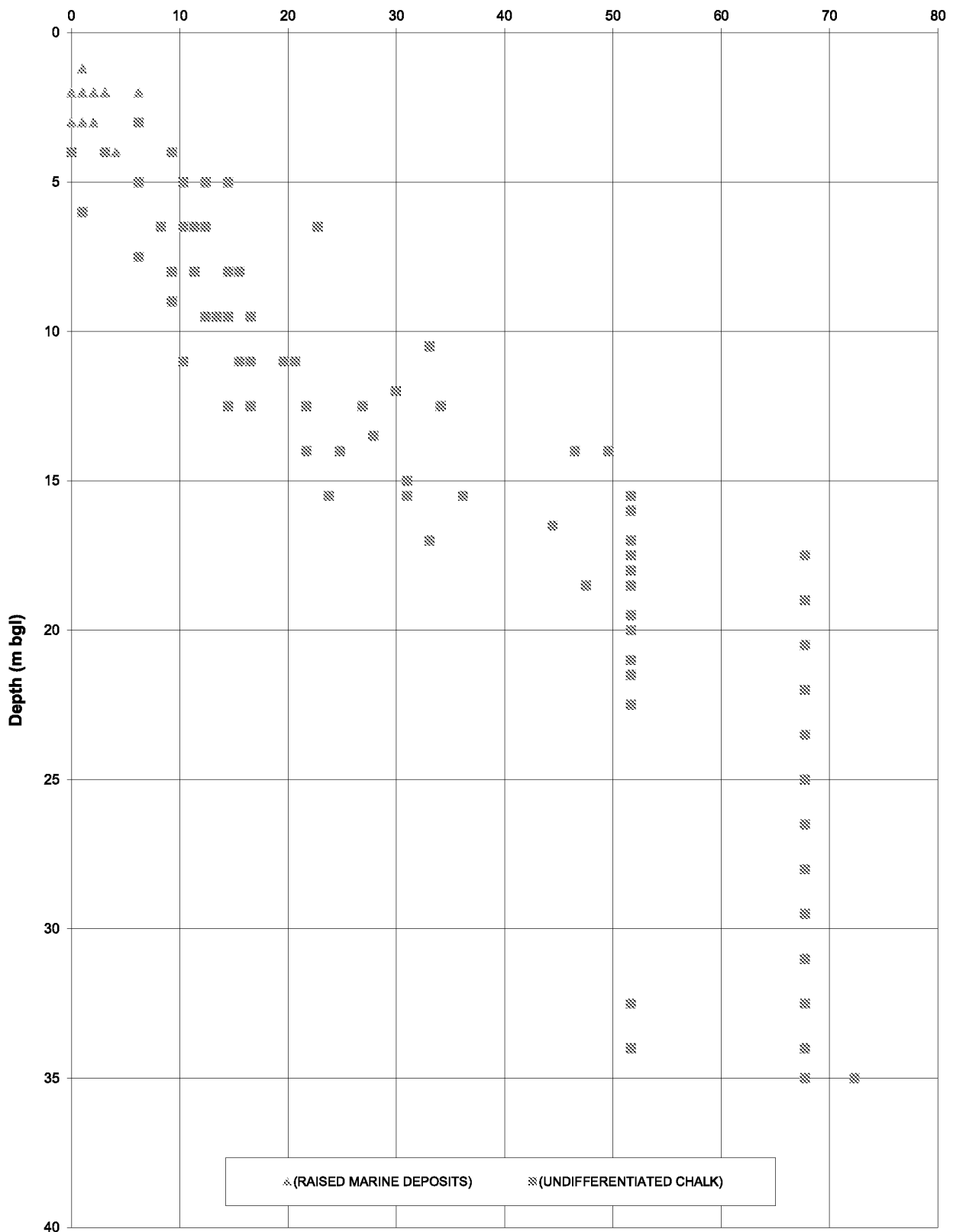
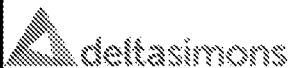


Figure 3 – Corrected SPT Results

Corrected* SPT 'N'



* Corrected for Energy Ratio only



TITLE:

Corrected* SPT, Depth and Strata Type
Oldlands Farm, Bognor Regis

DWN:

MJ

PROJECT NO:

20-1543.07

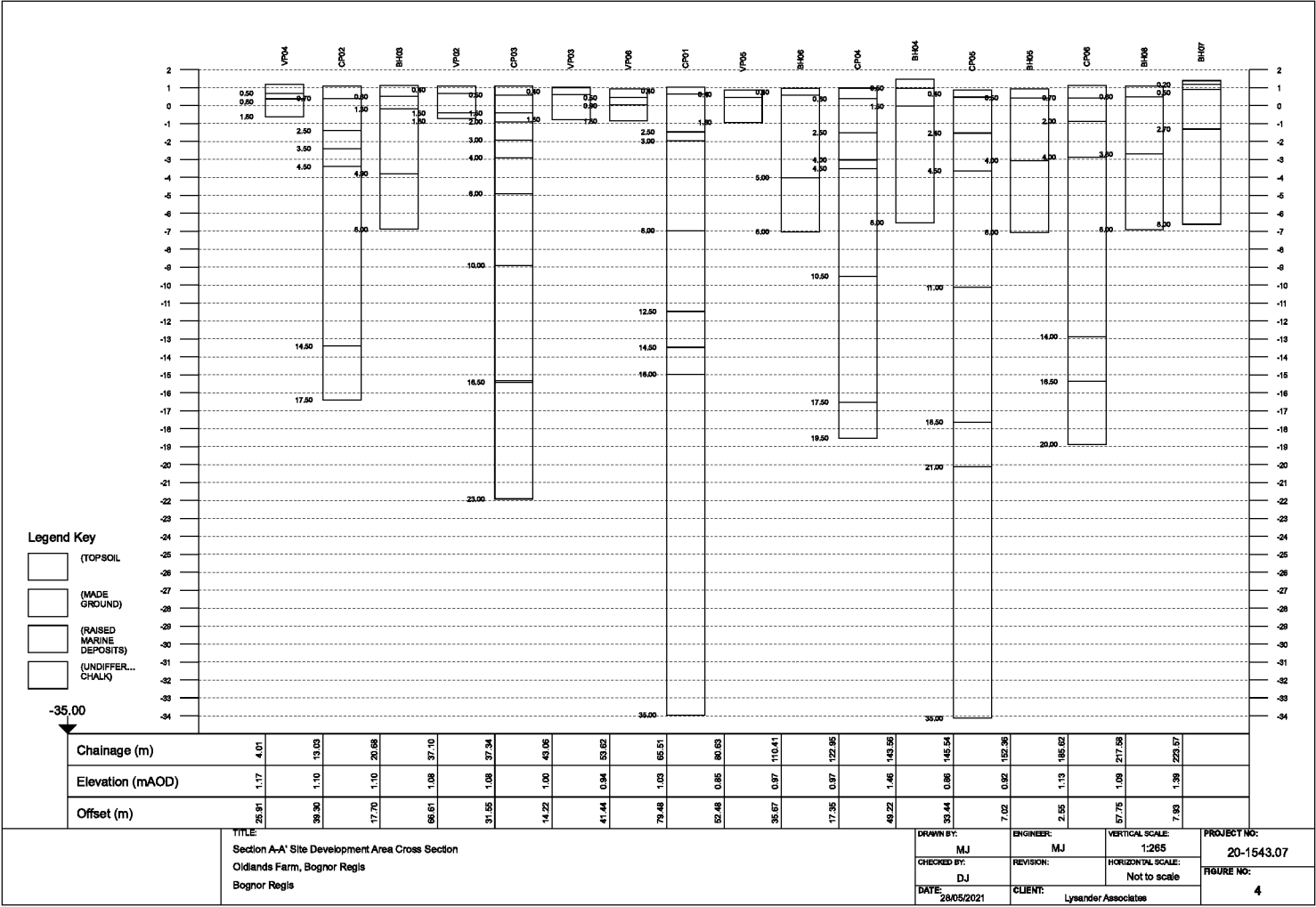
DATE:

24/06/2021

FIGURE NO:

3

Figure 4 – Geological Cross Section



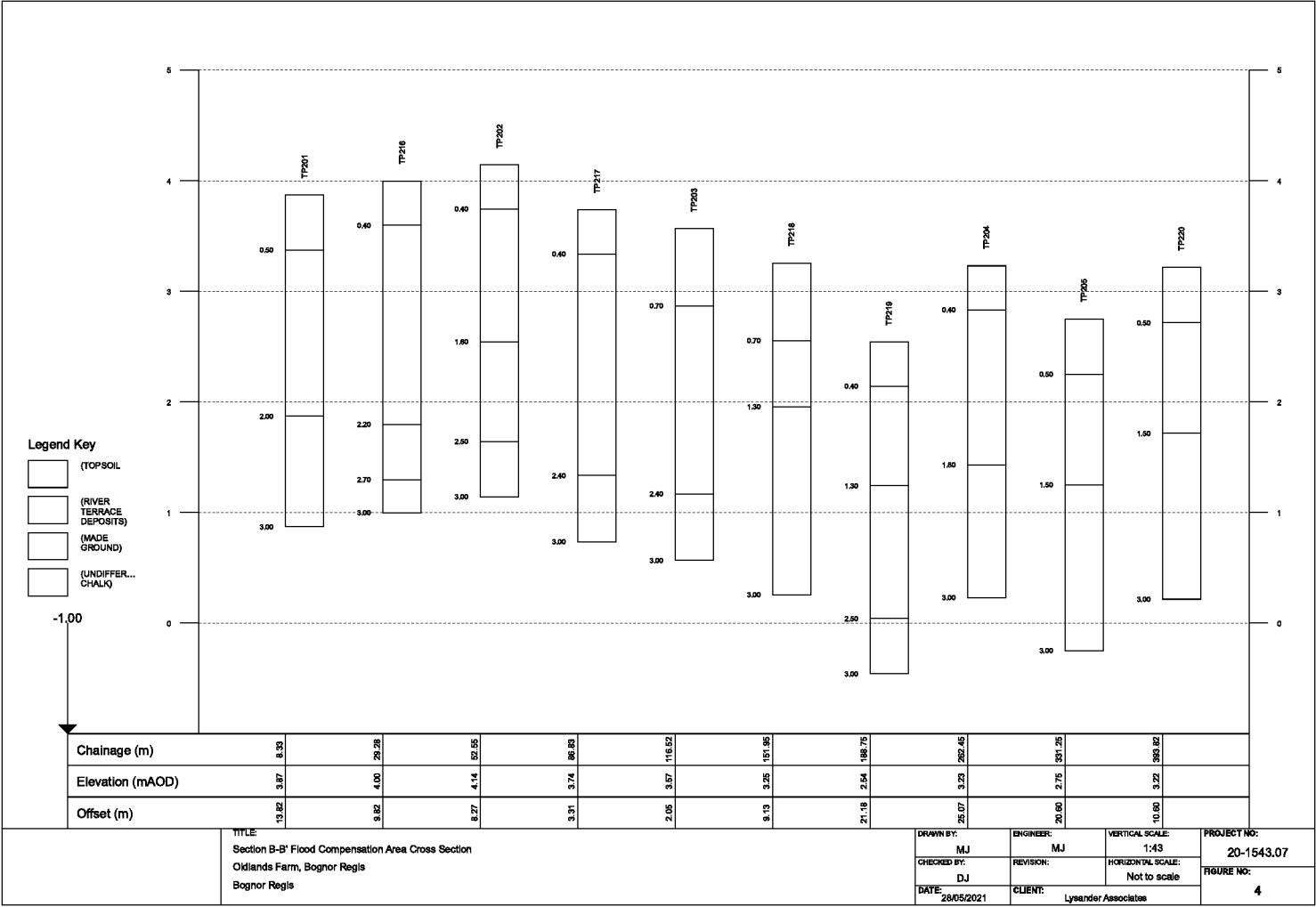
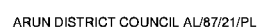


Figure 5 – Contour Plots





Site Plan Provided by Client

	TITLE Flood Compensation Area, River Terrace Deposits, Thickness (m) Oldlands Farm Bognor Regis		PROJECT NO: 20-1543.07	
	DESIGNED BY: MJ		FIGURE NO: 5a	
	DATE: 18 June 2021		SCALE: Not to Scale	
	DRAWN BY: KE		REVISION: 1	