



Dwyer Road

Phase 2 Ground Investigation Interpretative Report

For Reading Borough Council

Date: 1 June 2023

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Executive summary

<i>Site information and setting</i>	
Objectives	Phase 2 Ground Investigation has been commissioned to support the planning application and assist with design.
Client	Reading Borough Council
Site name and location	Dwyer Road, Reading, RG30 3PN
Proposed development	The site development proposals are understood to comprise a 4-storey apartment block and two-and three-storey house terraces with associated gardens, parking and a biodiverse green space.
Site description	The site is roughly square in shape and has an area of approximately 0.5 hectares and gently slopes from the north to the south. The site is currently undeveloped and surrounded by hoarding. Visible evidence of the historical land use as a residential care facility is limited to an area of asphalt hardstanding. A mixture of mature and semi-mature trees, and hedges are present around all site boundaries.
<i>Desk study summary</i>	
Topography	The site gently slopes from the north to the south, from an approximate elevation of 50.5m above Ordnance Datum (OD) in the north to 49m OD in the south.
Hydrology	There are no surface water features within 250m of the site. There are no active licensed surface water abstractions or discharges within 1km of the site.
Site History	The site was undeveloped until the construction of a residential care facility in the late-1960s/early-1970s, which was demolished around 2010.
Geology	Superficial: none recorded Solid: Lambeth Group / undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation
Natural geological hazards	Two natural cavities are recorded in the broad vicinity of the site (approximately 329m and 600m north-west).
Anthropomorphic geotechnical hazards	Stantec factual cavities database search report confirms that there is no known record of mining or mineral extraction having occurred on site. The site is located in both a clay and a sand and gravel safeguarded area due to the underlying Lambeth Group Localised Made Ground is anticipated due to historical land uses.
Hydrogeology	Lambeth Group: Secondary A Aquifer, Seaford Chalk / Newhaven Chalk Formation: Principal Aquifer. There are no active licensed groundwater abstractions within 1km of the site. The site is not within a groundwater Source Protection Zone (SPZ).
UXO risk	A non-specialist UXO assessment indicates a moderate bomb risk.

Other	The Environmental report did not identify any significantly elevated naturally occurring elements that may present a risk to future site users.
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Preliminary conceptual site model based on desk study

Potential contaminant sources	The Made Ground is a potential source of contamination. Fly-tipped waste may include asbestos containing materials. Ground gases (carbon dioxide and methane) may be generated by potential organic material within any Made Ground.
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Potential contaminant linkages (for receptors for which there is or will be a pathway)	Humans (resi with plant uptake / POS) Controlled waters – groundwater Plants Buildings / property
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Ground model proven by investigation

Ground and groundwater conditions encountered by investigation	The ground conditions as proven by the investigation undertaken at the site comprise: • Made Ground – between GL and 1.70m below ground level (bgl), comprising granular or cohesive materials with varied sub factions of materials. Anthropogenic elements include: brick, concrete, terracotta pipe, limestone, clinker, slate and asphalt. over • Topsoil – between GL and 0.25m bgl, comprising brown slightly gravelly silt.; over • Lynch Hill Gravel Member – between 0.20m and 4.50m bgl, comprising brown sands with various clay/silt and gravel factions and multi coloured clays with various sand and gravel factions.; over • Lambeth Group – between 1.30m and 6.80m bgl, comprising brown/multi coloured clays with various sand and gravel factions and brown sands with various clay and gravel factions.; over • Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) – between 2.10m and >20.0m bgl, comprising structureless chalk recovered as white gravelly silt. Clasts of weak to moderate density. Grade Dm. A dissolution feature is considered to be present at the location DP5. Groundwater was encountered at depths between 12.50m bgl and 13.30m bgl during the investigation. In general, groundwater was not encountered at shallow depths, being present between 12.50m – 13.30m bgl in the deep boreholes during the fieldworks. Post works monitoring notes that shallow wells are for the most part dry and the deeper well reporting groundwater levels between 9.10m – 9.17m bgl.
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Summary of geotechnical conclusions

Groundwork	Whilst no buried obstructions were encountered by this investigation, the possibility of buried obstructions being encountered remains. Excavation to proposed founding depth generally should be readily achievable with standard excavation plant. Excavations during investigation were generally stable, although slight spalling should be expected from the Made Ground and within the sands and gravels below the water table. Water seepages into excavations are likely to be adequately controlled by sump pumping.
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Foundations	In regards to the risk posed to the from dissolution features it is recommended that a post-demolition (site-wide) geophysical survey to manage risk of subsidence, with targeted investigation, as proven to be necessary is undertaken. Pending further investigation to delineate solution features, foundations are recommended to comprise: - Strip/trench fill foundations at minimum 0.90m bgl extending into medium dense (or better) sands or clays of the Lynch Hill Gravels. - Piled foundations where solution features are identified. A safe net bearing pressure of 200kN/m² is considered appropriate when founding in granular strata. And a net bearing pressure of 100kN/m² is considered appropriate when founding in the clays, (firm or better). Deepening of foundations/heave protection is likely to be required to allow for the effects of trees. Suspended because of depth of Made Ground and presence of medium shrinkage potential clay soils. Suspended over a void where within the influencing distance of trees.
Roads and pavements	For road / pavement design, a design CBR of <2.5% for the Made Ground and 5% the Lynch Hill Gravel Member is recommended.
Sustainable drainage	Preliminary permeability tests indicate permeabilities in the range of 2.39×10^{-5} - 9.15×10^{-5} m/s for the Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) at depth. Shallow soakaways are not recommended however consideration could be given to a deep borehole soakaway. Consideration must be given to the suitability of the ground for any proposed soakaways and any detrimental effects it could have on ground conditions or the water environment. Where Suds are proposed, and there are no alternative options, location-specific consideration to be given to risk of ground subsidence.
Buried concrete	Design Sulfate Class - DS-1 and ACEC Class AC-1. Equivalent to Design Chemical Class DC-1 for a 50 year design life for all soils.
Summary of geo-environmental assessment	
Human Health	- Pervasive PAH in the Made Ground. - Elevated concentrations of PAHs in Topsoil.
Phytotoxicity	No exceedances of the GAC.
Controlled waters	Soil leachate samples do not exceed the EQS and therefore low groundwater risk.
Radon:	No radon protection measures are required for new buildings at this location in line with current guidance.
Construction materials:	Plastic or bitumastic products to not be at risk from high concentrations of VOC.
Potable water supply pipes	Brownfield site and the presumption in the guidance is that barrier pipe will be used. However, the investigation and assessment has indicated no significant Contaminants of Concern and as such standard pipework may be suitable for the site following negotiations with the supply company.
Ground gases or vapours:	Ground gas monitoring proves CS1 condition apply, i.e., no protection measures required.

<i>Enabling works</i>	
Proposed mitigation measures	The mitigation measures proposed to remove unacceptable risks include: » The installation of a 600mm engineered cover system in gardens comprising a bonded geogrid break layer (e.g. TX160G), subsoil beneath a topsoil thickness of between 150mm and 300mm (PL1). » Fly-tipped waste to be removed prior to construction and appropriately disposed of (PL2). » Further investigation and testing of the topsoil to be undertaken to inform risk and potential re-use on site (PL3). The methodology for the remediation should be presented in a Remediation Strategy, which will need to be submitted to the warranty provider and the regulatory authorities for approval. Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works.
Waste management	» The Topsoil is likely to be classified as non-hazardous waste and subject to WAC testing may be able to be disposed of at an inert landfill. » The natural uncontaminated subsoils are likely to be classified as 'inert' waste and based on the WAC testing should be able to be disposed of at an inert landfill. » The Made Ground is likely to be classified as non-hazardous waste and subject to WAC testing may be able to be disposed of at an inert landfill.
<i>Future considerations</i>	
Further work	Following the ground investigation works undertaken to date, the following further works will be required: » supplementary ground investigation to further define the dissolution feature (and therefore extent of piling required), and confirm whether shallow foundations are suitable for the rest of the site. It is recommended that this includes a geophysical survey of the site as well as further probing; » supplementary investigation and testing of the topsoil on site in order to fully characterise this stratum to clarify risk to human health and determine suitability for re-use; » discussion and agreement with utility providers regarding the materials suitable for pipework; » discussions with regulatory bodies and the warranty provider regarding the conclusions of this report; » assessment of tree influence on foundations and design of foundations; » discussions with piling Contractors regarding conclusions of this report and design of the piles; » provision of geotechnical design for the Category 2 structures (foundations) pending the results of the supplementary investigation; » production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider); » remediation and mitigation works; and » verification of the remediation and mitigation works.

This Executive Summary forms part of Hydrock Consultants Limited report number 26888-HYD-XX-XX-RP-GE-1001 and should not be used as a separate document.

1. Introduction

1.1 Terms of reference

In February 2023, Hydrock Consultants Limited (Hydrock) was commissioned by Reading Borough Council (the Client) to undertake management, specification for a Phase 2 ground investigation utilising a third-party contractor, appointed and employed by the Client, at Dwyer Road, Reading, RG30 3PN (hereafter referred to as the site). Hydrock were then instructed to complete an interpretative report based on the findings.

The site was formerly a residential care facility; however, the site is currently an unoccupied parcel of land and the former structures demolished.

Hydrock understands that the proposed development is to comprise a 4-storey apartment block and two-and three-storey house terraces with associated gardens, parking and a biodiverse green space. A proposed development layout (HTA Design LLP Drawing RBC-DDR-HTA-A_DR_0100 Rev C), is presented in Appendix A.

The works have been undertaken in accordance with Hydrock's proposal referenced (Ref: 26888-HYD-XX-XX-FP-GE-1001, dated 5 March 2023) and the Client's instructions to proceed via email (Ref: FW: [Hydrock: 26887-SBSO] FW: 26887, 26888 - Amethyst Lane, Dwyer Road, dated 23 February 2023).

1.2 Objectives

Following the Hydrock Desk Study (Report Ref: 26888-HYD-XX-XX-RP-GE-1000, dated 22 February 2023), a Phase 2 Ground Investigation has been commissioned to support the planning application and assist with design. The ground investigation has been undertaken by a third party who have been contracted directly by the client. Hydrock are to perform part-time oversight throughout the ground investigation works and undertake the interpretive investigation report.

The objectives of the Phase 2 Ground Investigation are:

- » to resolve any geotechnical and geo-environmental uncertainties identified in the Phase 1 Desk Study by refining and updating the preliminary ground model, based on the conditions met in accordance with the principles of the Environment Agency's 'Land Contamination: Risk Management' (LCRM) (2021);
- » to identify any geo-environmental mitigation requirements to enable development to progress; and
- » to provide preliminary geotechnical recommendations for design.

1.3 Scope

The scope of the Phase 2 Ground Investigation (defined by Hydrock and undertaken by Soils Limited) comprises:

- » a preliminary ground investigation including trial pitting, dynamic probing, cable percussive boring, and Transport Research Laboratory (TRL) Dynamic Cone Penetrometer (DCP) testing to:
 - » obtain data on the ground and groundwater conditions of the site;
 - » allow collection of samples for geotechnical and chemical laboratory analysis;
 - » allow geotechnical field tests to be undertaken;
 - » install gas and groundwater wells;
- » gas concentration and groundwater level monitoring;
- » groundwater sampling;

- » geotechnical and chemical laboratory analysis (scheduled by Hydrock);

The interpretative Report (undertaken by Hydrock) comprises:

- » updating of the preliminary ground model;
- » preparation of a geotechnical risk register;
- » presentation of initial geotechnical design recommendations;
- » formulation of an updated Conceptual Site Model (CSM), including identification of any plausible contaminant linkages;
- » completion of a generic quantitative risk assessment of any identified chemical contaminants to establish 'suitability for use' under the current planning regime;
- » discussion of any potential environmental liabilities associated with land contamination (soil, water and gas); and
- » identification of outline mitigation requirements to ensure the site is 'suitable for use'.

1.4 Available information

The following documents, reports etc have been provided to Hydrock by Reading Borough Council for use in the preparation of this report:

- » Survey Solutions. 25 August 2022. Topographic Survey, Ref: 43955CVLS-01.
- » Middlemarch. September 2022. Tree Survey Plan, Ref: C158951B-01-01.
- » Survey Solutions. 5 October 2022. Utilities and Drainage Survey, Ref: 43955BWUG-01.
- » HTA Design LLP. 15 November 2022. Pre-Application Meeting 1. Ref: RBC-DRR-HTA-A_RP002.
- » HTA Design LLP. 22 November 2022. Pre-Application Meeting 1. Ref: RBC-ALR/RBC-DRR.
- » HTA Design LLP. 6 January 2023. Proposed Ground Floor, Ref: RBC-DDR- HTA-A_DR_0100 (Rev C).

It is understood that the Client commissioned assignment of the above documents and Hydrock has assumed full reliance can be placed upon their contents. Should this not be the case, Hydrock should be informed at the earliest opportunity.

In December 2022, Hydrock were commissioned to undertake a Phase 1 Desk Study (26888-HYD-XX-XX-RP-GE-1000, dated 22 February 2023) for the site (hereafter referred to as the Phase 1 Desk Study). Information, including a review of this report, has been used where applicable throughout.

1.5 Regulatory context and guidance

The geo-environmental section of this report is written in broad accordance with BS 10175:2011+ A2:2017, Environment Agency LCRM, (2021) and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

The methods used follow a risk-based approach, the first stage of which is a Phase 1 desk study and field reconnaissance, with any potential geo-environmental risks assessed qualitatively. This is done using the 'source-pathway-receptor contaminant linkage' concept to assess risk as introduced in the Environmental Protection Act 1990 (EPA, 1990). Any potential geotechnical risks are also assessed from the Phase 1 desk study and site reconnaissance stage. These items have been considered as part of the Phase 1 Desk study a summary of which is presented in this report.

Phase 2 comprises intrusive ground investigation work and testing. The factual information from the desk study and the ground investigation are used to develop the updated Conceptual Site Model (CSM). This CSM is based on a ground model of the site physical conditions and an exposure model of the possible contaminant linkages. The CSM forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines. This GQRA might lead to more Detailed Quantitative Risk Assessment (DQRA).

Professional judgement is then used to evaluate the findings of the risk assessments and to provide recommendations for the development.

The geotechnical section of this report is prepared in general accordance with BS EN 1997-1+A1: 2013, BS EN 1997-2:2007 and BS 8004:2015. This report constitutes a Ground Investigation Report (GIR) as described in Part 2 of Eurocode 7 (BS EN 1997-2) (EC7). However, it is not intended to fulfil the requirements of a Geotechnical Design Report (GDR) as specified in EC7.

Where relevant the relevant requirements of the current edition of NHBC Standards have also been applied.

The geo-environmental and geotechnical aspects are discussed in separate sections. Throughout the report the term 'geotechnical' is used to describe aspects relating to the physical nature of the site (such as foundation requirements). The term 'geo-environmental' is used to describe aspects relating to ground-related environmental issues (such as potential contamination). However, it should be appreciated that this is an integrated investigation and these two main aspects are inter-related. Designers should take all aspects of the investigation into account.

Remaining uncertainties and recommendations for further work are listed in Section 9 and Section 10.

2. Phase 1 Desk Study (summary)

2.1 Introduction

Hydrock undertook a Phase 1 Desk Study for the site in February 2023. The following section is a summary of the pertinent information presented in the Phase 1 Desk Study, however, the full report must be read in conjunction with this report.

2.2 Site location

The site is located in Southcote, around 3.5km south-west of Reading city centre. The National Grid Reference of the approximate centre of the site is 468234E, 171887N. A Site Location Plan (Ref: 26888-HYD-XX-XX-DR-GE-1000, dated 21 January 2023) is presented in Appendix A.

2.3 Site description

The site is roughly square in shape and has an area of approximately 0.5 hectares and gently slopes from the north to the south, from an approximate elevation of 50.5m above Ordnance Datum (OD) in the north to 49m OD in the south.

The site is currently undeveloped and surrounded by hoarding. Visible evidence of the historical land use as a residential care facility is limited to an area of asphalt hardstanding in the south near the entrance from Dwyer Road.

A mixture of mature and semi-mature trees, and hedges are present around all site boundaries. A comprehensive vegetation survey has been undertaken by Middlemarch. The Tree Survey Plan (Ref: C158951B-01-01, dated September 2022) is presented in Appendix A.

2.4 Site history

The site was undeveloped until the construction of a residential care facility in the late-1960s/early-1970s, which was subsequently demolished around 2010, it is not currently known if the foundations were also removed. The surrounding area has been gradually developed into a suburban residential neighbourhood since the 1930s.

2.5 Geology

There are no superficial deposits recorded on, or within the immediate vicinity of, the site.

The Solid Geology comprises the Lambeth Group (variable sequences of mainly clay, some silty or sandy, with sands and gravels) over undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation (hard nodular chalks with interbedded soft to medium hard chalks and marls.), which potentially outcrops near surface in the far south of the site.

2.6 Hydrogeology

The Environment Agency classes the geology as outlined in Section 2.5 as:

- » Lambeth Group: Secondary A Aquifer.
- » Seaford Chalk / Newhaven Chalk Formation: Principal Aquifer.

There are no active licensed groundwater abstractions within 1km of the site. The site is not within a groundwater Source Protection Zone (SPZ). The site is indicated to be in an area with a moderate risk of groundwater flooding.

2.7 Hydrology

There are no surface water features within 250m of the site. The closest primary surface water feature is the Holy Brook, situated approximately 500m to the south of the site.

There are no active licensed surface water abstractions or discharges within 1km of the site.

2.8 Flood risk

The proposed development is in Flood Zone 1 with a low probability of flooding from rivers or the sea. The Groundsure report shows that a small area in the north of the site has a 1-in-30-year return rate of 0.10-0.30m pluvial flooding.

No further consideration of flood risk is undertaken in this report. Specialist flood risk advice should be sought with regard to drainage and flooding.

2.9 Mining or mineral extraction

The Stantec factual cavities database search report (Ref: 332511449//CBH/SC/HG/JN, dated 16 February 2023) details the distance, location and nature of recorded cavities in the vicinity of site.

This report confirms that there is no known record of mining or mineral extraction having occurred on site.

The site is located in both a clay and a sand and gravel safeguarded area due to the underlying Lambeth Group. A Minerals Resource Assessment may be required as part of the planning application. Further advice should be sought from the local authority.

2.10 Natural chalk cavities

Two natural cavities are recorded in the broad vicinity of the site (approximately 329m and 600m north-west).

2.11 Natural ground instability

Trees and hedges are present around the site boundaries and sporadically across the site. Cohesive deposits of the Lambeth Group may be affected by potential for shrink-swell ground movements in clays as a result of changes in moisture content from removal or growth of trees.

2.12 Waste management

There are no current or historical waste management sites recorded within 250m of the site.

2.13 Regulatory information

There are no sites within 500m of the site that have regulatory controls relevant to the site.

2.14 Natural soil chemistry

The Phase 1 Desk Study did not identify any significantly elevated naturally occurring elements that may present a risk to future site users.

2.15 Radon and ground gas

The Phase 1 Desk Study indicates that the south-east corner of the site is recorded to be a Radon Affected Area where recorded radon levels in 1-3% of homes are above the action level (remainder of the site not in a Radon Affected Area). However, no radon protection measures are required for new buildings at this location in line with current guidance.

2.16 Unexploded ordnance (UXO)

The Phase 1 Desk Study indicates a low risk and no further assessment is required with regard to UXO in relation to ground investigation. Further assessment may be considered prudent for construction activities.

3. Initial Conceptual Site Model

3.1 Introduction

The initial Conceptual Site Model (iCSM) was developed in the Phase 1 Desk Study and is largely duplicated for completeness. The formulation of an iCSM is a key component of the LCRM methodology. The iCSM incorporates a ground model of the site physical conditions and an exposure model of the possible contaminant linkages; it forms the basis for GQRA in accordance with current guidelines.

3.2 Ground model

The preliminary ground model presented in Section 2 provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 3.3) and the preliminary geo-environmental exposure model (Section 3.4).

3.3 Geotechnical hazard identification

3.3.1 Context

The preliminary geotechnical hazard identification has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622.

The following section sets out the identified geotechnical hazards and the development elements potentially affected (see Table F.1 in Appendix G for further information).

3.3.2 *Plausible geotechnical hazards*

Plausible geotechnical hazards identified at the site are:

- » Uncontrolled Made Ground (variable strength and compressibility).
- » Soft / loose compressible ground (low strength and high settlement potential).
- » Shrinkage / swelling of the clay fraction of soils under the influence of vegetation.
- » Variable lateral and vertical changes in ground conditions.
- » Potential for high sulphates in the soils.
- » Obstructions.
- » Existing below ground structures to remain (e.g., existing services)
- » Shallow groundwater.
- » Changing groundwater conditions.
- » Risk from flooding.
- » Loose Made Ground, leading to difficulty with excavation and collapse of side walls.
- » Solution features in Chalk.
- » Dissolution (associated with 'wet rock head').

3.3.3 *Potential development elements affected*

Development elements potentially affected by geotechnical hazards are:

- » Buildings – foundations and ground floor slabs.
- » Roads and pavements.
- » Services.

- » Gardens.
- » Concrete below ground.
- » Construction staff, vehicles and plant operators.

Health and safety risks to site Contractors and maintenance workers have not been assessed during these works and will need to be considered separately during design.

The above plausible geotechnical hazards and development elements affected have been carried forward for investigation and assessment. The investigation is presented in Section 4 and the assessment is presented in Section 5.

3.4 Geo-environmental exposure model

3.4.1 Context

The preliminary exposure model is used to identify geo-environmental hazards and to establish potential contaminant linkages, based on the source-pathway-receptor (SPR) approach.

A viable contaminant linkage requires all the components of an SPR to be present. If only one or two are present, there is no linkage and no further assessment is required.

3.4.2 Potential contaminants

For the purpose of this assessment the potential contaminants have been separated according to whether they are likely to have originated from an on-site or off-site source.

3.4.2.1 Potential on-site sources of contamination

- » Made Ground and stockpiles associated with historical construction and demolition activities, possibly including elevated concentrations of metals, metalloids, asbestos fibres, asbestos containing materials, polycyclic aromatic hydrocarbons and petroleum hydrocarbons (S01).
- » Fly-tipped waste materials, possibly including asbestos containing materials (S02).
- » Ground gases (carbon dioxide and methane) from organic materials in the Made Ground (S03).

3.4.2.2 Potential off-site sources of contamination

No potential off-site sources of contamination have been identified.

3.4.3 Potential receptors

The following potential receptors in relation to the proposed land use have been identified.

- » People (neighbours, site end users) (R01).
- » Development end use (buildings, utilities and landscaping) (R02).
- » Groundwater: Secondary A Aquifer status of the Lambeth Group and Principal Aquifer status of the Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) (R03).

3.4.4 Potential pathways

The following potential pathways have been identified.

- » Ingestion, skin contact, inhalation of dust and outdoor air by people (P01).
- » Root uptake by plant life (P02).
- » Migration of contaminant via leachate migration into the aquifers of the Lambeth Group and Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) (P03).
- » Migration of contaminants via base flow through the Lambeth Group and the Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) (P04).

- » Migration and build-up of ground gases (P05).

Health and safety risks to site development contractors and maintenance workers have not been assessed as part of this study and will need to be considered separately.

The above sources, pathways and receptors have been considered as part of the Preliminary Risk Assessment in accordance with LCRM (Environment Agency, 2021), are considered to be plausible in the context of this site and should be carried forward for investigation and assessment. The Source – Pathway – Receptor linkages are presented in Appendix F (Table F.2).

A summary of the plausible linkages is presented on the Initial Conceptual Model provided in Appendix A. (Hydrock Drawing 26888-HYD-XX-XX-DR-GE-1001, dated 23 January 2023).

3.4.5 *Potential implications of climate change*

Climate change has the potential to change the risk profile for conceptual site models and associated contaminant linkages. The impact of climate change on the CSM is site-specific, and a qualitative assessment of the potential impact of climate change on the CSM for this site is summarised below. The assessment has primarily utilised the guidance in Environment Agency (2010)¹ and SoBRA (2022)² which set out the UK context to climate change and land contamination. Both guidance documents advocate a “what if” scenario approach in the context of changes in ambient temperatures, an increase in the frequency of extreme rainfall/storm events and heatwaves/droughts, and long-term changes in groundwater and sea levels.

Those “what if” scenarios that are relevant to this CSM are:

- » Increased long-term rainfall leading to increased infiltration and seasonally higher groundwater and water levels in surface waters.
- » Increased frequency and/or magnitude of extreme rainfall events leading to short-term surface flooding, surface water run-off, groundwater flooding, and/or land-based erosion.
- » Occurrence of extreme cold and hot weather events leading to changes in ground conditions such as soil temperature, evapo(trans)piration, and soil moisture (for example freeze-thaw effects and desiccation), decreased infiltration and fall in groundwater and surface water levels.
- » Long-term decrease in rainfall leading to lower infiltration and fall in groundwater and surface water levels.

¹ Environment Agency, 2010. *Guiding Principles for Land Contamination. Part 2. FAQs, technical information, detailed advice and references*, March 2010.

² SoBRA, 2022. *Guidance on Assessing Risk to Controlled Waters from UK Land Contamination Under Conditions of Future Climate Change*, Society of Brownfield Risk Assessment, August 2022.

4. Ground Investigation

4.1 Site works

Reading Borough Council instructed 'Soils Limited' to undertake the ground investigation at the site. The fieldwork took place between 14 and 17 March 2023. The exploratory hole locations, exploratory logs, including details of ground conditions, soil sampling, in situ testing and any installations, are presented in the Soils Limited factual report presented in Appendix B.

The ground investigation comprised:

- » 6 trial pits to a maximum depth of 4.00m below Ground Level (bgl);
- » Transport Research Laboratory Dynamic Cone Penetrometer (TRL DCP) testing;
- » 8 dynamic probes to a maximum depth of 10.00m bgl;
- » 2 cable percussion boreholes to a maximum depth of 20.00m bgl; and
- » Falling head permeability tests within boreholes to determine preliminary infiltration rates.

Table 4.1: Summary of monitoring installations

Location	Standpipe diameter	Screen top and base depth (m bgl)	Strata targeted
BH01	50	8.00 to 20.00	Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)
BH02	50	0.50 to 1.50	Made Ground
BH02	50	2.50 to 3.50	Lynch Hill Gravel Member

Monitoring wells were designed by Hydrock based on drillers logs.

4.2 Geo-environmental testing

The chemical test certificates for the laboratory testing are presented in the Soils Limited factual report presented in Appendix B. Hydrock scheduled the soil samples for chemical testing, however, additional items and changes to the testing was instructed by Soils Limited, notably:

- » Hydrock instructed that Hydrock's minimum determinand suites were to be used however Soils Limited utilised their own testing suites;
- » Additional screening for Total Petroleum Hydrocarbon Criteria Working Group (TPH-CWG) plus Methyl tert-butyl ether (MTBE) & Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX); and
- » Screening for Polychlorinated Biphenyls (PCBs).

Wherever possible, UKAS and MCERTS accredited procedures have been used.

The geo-environmental analyses undertaken on soils are summarised in Table 4.2.

Table 4.2: Geo-environmental analyses of soils

Determinand Suite	Made Ground	Topsoil	Lynch Hill Gravel Member
Soils Limited soil suite 1 ¹	4	2	5
TPH-CWG including BTEX+MTBE	4 ²	2	5 ³
Soils Limited soil suite 1 leachate*	1	-	-

Waste Acceptance Criteria (WAC) Suite	1	-	1
PCB Screen ⁴	4	2	5

¹Soils Limited soil and leachate suite comprises: metals, Extractable Petroleum Hydrocarbons (EPH), speciated Polycyclic Aromatic Hydrocarbons (PAH) and asbestos screen.

²Only one sample scheduled by Hydrock.

³Testing scheduled by Soils Ltd.

⁴Testing scheduled by Soils Ltd.

The soils chemical test data are interpreted and assessed in Sections 7.3 and 7.4.

4.3 Geotechnical testing

The geotechnical tests scheduled by Hydrock are summarised below and the test certificates are presented in the Soils Limited factual report presented in Appendix B. Wherever possible, UKAS accredited procedures have been used.

Table 4.3: Summary of sample numbers for geotechnical tests

Test	Made Ground	Lynch Hill Gravel Member	Lambeth Group	Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)
Natural moisture content	-	3	1	-
Atterberg limits	-	3	1	-
Particle size distribution (sieve)	1	2	-	-
Sulfate and aggressive chemical environment classification for buried concrete classification (full BRE SD1 suite)*	1	5	2	1
Saturated Moisture Content	-	-	-	5
Effective Stress - Consolidated Undrained Triaxial test	-	1	-	-

*Hydrock scheduled Full BRE SD1 suites but reduced suites undertaken by the contractor.

The geotechnical test data are summarised in Section 5 and interpreted in Section 6.

4.4 Constraints

Hydrock attended the site on a part-time basis, information provided by third parties has been used in good faith and is taken at face value.

5. Ground investigation records and data

5.1 Physical ground conditions

5.1.1 Summary of strata encountered

The following presents a summary of the properties of the ground and groundwater conditions encountered by Soils Limited, based on field observations, interpretation of the field data and laboratory test results, taking into account drilling, excavation and sampling methods, transport, handling and specimen preparation.

All relevant data from the investigation discussed in Section 4 are used from this point forward.

Details of the Soils Limited ground investigation works are provided in the logs in Appendix B, a summary of the ground model is presented in Table 5.1 and the individual strata are described in the sections below.

Table 5.1: Strata encountered

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)	Thickness (m) (average)
Asphalt	GL	0.13	0.13	n/a
Made Ground	GL	0.20 – 1.70	0.20 – 1.70	0.85
Topsoil	GL	0.10 – 0.25	0.10 – 0.25	0.20
Lynch Hill Gravel Member	0.20 – 1.70	1.30 – 4.50	1.00 – 4.30	2.53
Lambeth Group	1.30 – 4.50	2.10 – 6.80	0.80 – 2.60	1.56
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	2.10 – 6.80	>4.00 – >20.00	>0.30 – >13.20	Not proven

5.1.2 Bituminous bound pavement

Asphalt was encountered in TP5 only between GL and 0.13m bgl.

5.1.3 Made Ground

Made Ground was localised but generally found in the southern and eastern parts of site at select locations (BH1 – 2, TP3 – 5 and DP5). Made Ground was encountered from GL and was between 0.20m to 1.70m thick, with an average thickness of 0.85m.

Generally variable composition being either granular or cohesive, with varied sub factions of materials. Anthropogenic elements include: brick, concrete, terracotta pipe, limestone, clinker, slate and asphalt.

5.1.4 Topsoil

Where the Made Ground was not encountered (TP1 – 2), the exploratory holes encountered topsoil overlying the natural soils from GL. The Soils Limited logs have not differentiated between topsoil and Made Ground materials. Hydrock consider that topsoil is likely present across the majority of the site due to observations however the Soils Limited logs indicate a considerable thickness of

Made Ground from surface, It is recommended that this be revisited as part of a supplementary ground investigation, if it is desired to reuse the material.

Topsoil, were noted on the logs, was between 0.10m and 0.25m thick, with an average thickness of 0.22m. The topsoil comprised brown slightly gravelly silt.

For the purposes of this report, topsoil is defined as the upper layer of an in situ soil profile, usually darker in colour and more fertile than the layer below (subsoil), which is a product of natural chemical, physical, biological and environmental processes, but does not imply compliance with BS 3882:2015. Reuse of topsoil as a growing medium at the site should be determined by the landscape architect or the landscape Contractors.

5.1.5 *Lynch Hill Gravel Member*

Whilst the BGS maps indicate no superficial deposits to be present on site, the investigation has found sands and flint gravels near surface across the whole site. Hydrock consider the rounded gravels and sands to be part of the Lynch Hill Gravel Member which is noted to be 900m to the north east on BGS mapping.

Lynch Hill Gravel Member was encountered underlying the Made Ground or topsoil across the site. Lynch Hill Gravel Member is between 1.00m and 4.30m thick, with an average thickness of 2.53m.

This generally consisted of brown sands with various clay/silt and gravel factions and multi coloured clays with various sand and gravel factions.

5.1.6 *Lambeth Group*

Lambeth Group was encountered underlying the Lynch Hill Gravel Member across the site and is between 0.80m and 2.60m thick, with an average thickness of 1.56m where the base was proven.

This generally consisted of brown/multi coloured clays with various sand and gravel factions, and brown sands with various clay and gravel factions.

5.1.7 *Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)*

Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) was encountered underlying the Lambeth Group across the site down to a maximum proven depth of 20.00m bgl (base not proven).

This generally consisted of structureless chalk recovered as white gravelly silt. Clasts of weak to moderate density. Grade Dm.

5.2 *Visual and olfactory evidence of contamination (soil)*

In addition to the more common man-made constituents described above in Section 5.1.3, visual and olfactory evidence of contamination was noted in TP5, with a slight hydrocarbon odour observed in the Made Ground between 0.13m – 0.40m bgl.

5.3 *Evidence of potential dissolution features and dynamic probe data*

There is evidence of a potential dissolution feature at and around the dynamic probing location DP5 where between 1.90m – 4m depth bgl extremely loose ground was encountered with a possible void below 4m to around 6m.

A trial pit was undertaken at this location (TPDP5) to determine the material present and/or identify a shallow void. The materials encountered in the trial pit were noted to be Made Ground to 0.50m bgl, over sand and gravel to 1.6m bgl underlain by variable layers of sand and clay. What is thought to be Lambeth Group (laminated sandy clay) was encountered between 3.7m and 4m towards the base of the trial pit.

It is suspected that the top of the chalk is encountered below a depth of 4m and has historically undergone an amount dissolution that has caused the overlying ground to collapse into the void, which has subsequently then bulked and loosened.

No evidence of a hollow was observed in the ground surface suggesting that the shallower coarser materials are offering some arching capacity.

The rest of the dynamic probe locations did not indicate further similar loose ground conditions however due to encountering one potential dissolution feature, more may be present on site.

5.4 Groundwater

5.4.1 Groundwater observations and levels

Groundwater encountered during the investigation is listed in Table 5.2. A groundwater observation represents the depth at which groundwater was first observed and is likely to be deeper than the actual water table level at that location.

Table 5.2: Groundwater occurrence

Stratum	Date	Location	Fieldwork		Comment
			Groundwater observation (m bgl)	Rose to after 20 mins (m bgl)	
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	14/03/23	BH1	13.30	12.50	Groundwater strike
	15/03/23	BH2	12.50	12.50	

5.4.2 Permeability tests

The results of permeability testing using falling head analysis is summarised in Table 5.3. The results sheets are presented in the Soils Limited factual report presented in Appendix B.

Table 5.3: Permeability test results

Stratum	Borehole No.	Base of test (m bgl)	Permeability Coefficient (k) (m/s)		
			Run 1	Run 2	Range
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	1	10.00	8×10^{-5}	9.15×10^{-5}	2.39×10^{-5} - 9.15×10^{-5}
	2	10.00	2.39×10^{-5} *	-	n/a

Where less than two tests were possible in a particular location the results provided should be considered indicative only and should not be used for design purposes. Multi-day testing should be undertaken.

The tests undertaken in BH1 and BH2 at 20.00m and 15.00m bgl respectively had limited infiltration area available due to the depth of casing in the borehole.

5.4.3 Groundwater summary

In general, groundwater was not encountered at shallow depths, being present between 12.50m – 13.30m bgl in the deep boreholes during the field works. Post works monitoring notes that shallow wells are for the most part dry and the deeper well reporting groundwater levels between 9.10m – 9.17m bgl.

The Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) recorded permeability rates between 2.39×10^{-5} - 9.15×10^{-5} m/s.

5.5 Ground gases

Records from the gas monitoring boreholes are presented in the Soils Limited factual report, presented in Appendix B, and summarised in Table 5.4.

Three monitoring visits have been undertaken and the monitoring programme is complete. The data are assessed in Section 7.6.

Table 5.4: Range of ground gas data

Stratum	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Steady flow rate (L/hr)
Made Ground	0.0	0.1 – 3.5	16.1 – 21.2	0.0
Lynch Hill Gravel	0.0	2.4 – 3.4	16.1 – 17.6	0.0
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	0.0	0.0 – 0.1	16.7 – 21.0	0.0

5.6 Geotechnical data

5.6.1 Introduction

Laboratory test results are contained in the Soils Limited factual report presented in Appendix B with *in situ* test results shown on the relevant exploratory hole log or datasheet in the Soils Limited factual report presented in Appendix B. The following sections summarise the main findings and provide interpretation where appropriate.

5.6.2 Plasticity

The volume change potentials in terms of NHBC Standard (Chapter 4.2) with respect to building near trees have been determined from the results of plasticity index tests on samples of soil. These are summarised in Table 5.5.

Table 5.5: Volume change potential

Stratum	No. of tests	Plasticity Index			Modified Plasticity Index			Plasticity designation	Volume Change Potential
		Min.	Max	Av.	Min.	Max	Av.		
Lynch Hill Gravel Member	3*	25	29	27	25	29	27	Non-plastic - Medium	Non-plastic - Medium
Lambeth Group	1	27	27	-	27	27	-	Medium	Medium

*One out of 3 tests reported as non-plastic.

5.6.3 Particle size distribution

Particle Size Distribution test (PSDs) results are summarised in Table 5.6.

Table 5.6: PSD results summary

Stratum	No. of tests	Silt/Clay %	Sand %	Gravel %	General description
Made Ground	1	24	52	24	Silty/clayey gravelly SAND
Lynch Hill Gravel Member	2	5 - 7	18 - 90	3 - 77	Silty/clayey sandy GRAVEL and slightly gravelly slightly silty/clayey SAND.

5.6.4 Soil strength

Table 5.7 summarises information pertaining to the shear strength of the soils according to geological stratum. Factual results are summarised for laboratory tests, field tests (e.g. hand shear vane) and uncorrected Standard Penetration Tests (SPT). Where the SPT is used to infer shear strength by published correlation, this is also tabulated.

Table 5.7: Soil strength results and derived values

Stratum	No. of tests	SPT (N-value) (range)	c _u (kPa)	c' (kPa)	phi' (°)	Method
Lambeth Group	1	-	7	-	-	Triaxial – Laboratory.
Lambeth Group	1	11	49.5*	-	25	SPT – cable percussion.
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	14	6 - 14	27 - 63	-	-	SPT – cable percussion.

*Correlation with Stroud (1975) based on 'average' plasticity

5.6.5 Relative density

Table 5.8 summarises information pertaining to the relative density of the granular soils according to geological stratum. Factual results are summarised for laboratory tests, field tests (e.g. SPT, CPT, dynamic probe correlation).

Table 5.8: Relative density results and derived values

Stratum	No. of tests	Method	SPT (N-value) (Range)	phi' (°)
Lynch Hill Gravel Member	6	SPT – cable percussion (Peck et. al. (1967)).	12 - 35	30 - 37
Lambeth Group	2	SPT – cable percussion (Peck et. al. (1967)).	14 - 21	31 - 33

5.6.6 Subgrade stiffness

The subgrade stiffness (CBR) results are summarised in Table 5.9. Topsoil will be stripped and so is not considered. The Made Ground varies considerably in depth and composition and so a value of <2.5% has been inferred as the tests are not carried out adjacent to trial pit locations. It is assumed, from correlation with other holes, that the values reported indicate the Lynch Hill Gravel Member,

Table 5.9: CBR results and derived values

Stratum	No. tests	Method	CBR (%) (Range)
Made Ground	-	<i>Inferred</i>	<2.5%
Lynch Hill Gravel Member	6	<i>in situ</i> TRL DCP test	6 - 40

Where using the IAN method, 'k' has been back calculated from the Equivalent CBR.

5.6.7 Sulfate content

In accordance with BRE (Special Digest 1), the Design Sulfate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in Table 5.10. The assessment summary sheets are presented in Appendix C.

Hydrock note that sample ref: 121827-9 on report ref: 121827 has the incorrect location assigned, it is thought this sample noted to be at 5.50m bgl from TP05 should be from BH01 as the trial pit did not extend to this depth and BH01 is missing a scheduled test. This has been assumed for the purposes of the Hydrock report.

Table 5.10: Aggressive chemical environment concrete classification

Stratum	No. tests	DS	ACEC
Made Ground	1	DS-1	AC-1
Lynch Hill Gravel Member	5	DS-1	AC-1
Lambeth Group	2	DS-1	AC-1
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	1	DS-1	AC-1

5.6.1 Saturation Moisture Content Testing

Table 5.11 summarises information pertaining to the density characteristics of the Chalk, based on laboratory test data.

Table 5.11: Saturation Moisture Content Test Results

Parameter Stratum	No. of tests	Saturation Moisture Content (range) Mg/m ³	Dry Density (range) Mg/m ³	Density classification (CIRIA 574)
Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)	5	28 - 31	1.47 - 1.54	low

6. Geotechnical assessment

6.1 Geotechnical categorization of the proposed development

Eurocode 7, Section 2 advocates the use of geotechnical categorization of the proposed structures to establish the design requirements.

The proposed development is to comprise a 4-storey apartment block and two-and three-storey house terraces with associated gardens, parking and a biodiverse green space.

Notwithstanding this, the potential dissolution feature identified in DP5 requires a piled foundation, additional investigation should be undertaken to further delineate this feature and confirm foundation solutions for each plot. With the supplementary investigation Geotechnical Category 1 could be applied to the majority of the site if suitability for shallow trench fill foundations is confirmed.

Based on the above, for the purposes of this investigation, the proposed structures have been classed as Geotechnical Category 2 pending further investigation.

For Category 2 structures, the Geotechnical Category should be re-assessed at the design stage and specific geotechnical design (in addition to this investigation), is required.

Following the ground investigation and as part of the assessment provided in the following section, the preliminary geotechnical hazard identification undertaken in Section 3.3 has been updated.

Assessment has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622. The preliminary Geotechnical Risk Register following investigation is provided in Appendix G (Table J.3) and will need to be updated during future design works.

6.2 Groundwork

6.2.1 Site preparation

Whilst no buried obstructions were encountered by this investigation, the possibility of buried obstructions being encountered remains due to the development history of the site. Therefore, it is recommended that an allowance be made for breaking out obstructions, for example provision of pneumatic breakers for site plant. If underground structures cannot be removed, they will need to be surveyed in three dimensions and the new structures will need to be designed to accommodate them.

Topsoil should be removed from beneath all building and hardstanding areas.

6.2.2 Groundworks

Following breaking out of hardstanding and obstructions, excavation of shallow soils should be readily undertaken by conventional plant and equipment.

Trial pit faces were noted to remain generally vertical without collapse. The faces of shallow, near vertically sided excavations put down at the site are likely to remain stable for short periods of time.

A risk assessment of the stability of any open excavation should be undertaken by a competent person and appropriate measures adopted to ensure safe working practise in and around open excavations. Further guidance on responsibilities and requirements for working near, and in, excavations can be obtained from the Construction Design and Management Regulations (2015); Construction Information Sheet 47: Inspections and Reports (2005) and HSG47: Avoiding Danger from Underground Services.

To ensure no loads are imposed on the sides of the excavation, spoil should not be placed immediately adjacent to the excavation. Spoil should be placed a suitable distance from the side of the excavation (as assessed by a competent person).

Based on site observations groundwater is not anticipated to be present in shallow excavations and, if any, the rate of water ingress to the proposed excavations is likely to be slow. In these circumstances, groundwater control by sump pumping is likely to be sufficient.

However, it should be recognised that groundwater levels may vary from those at the time of the investigation, for example in response to seasonal fluctuations and the timing of construction may dictate the extent of groundwater control required.

Any water pumped from excavations may need to be passed via settlement tanks (to reduce suspended solids) before being discharged to the sewer. Discharge consents may also be required.

6.2.3 *Earthworks/reuse of site-won materials*

At this stage, Hydrock is not aware of proposals for earthworks at the site.

Should earthworks be required, supplementary earthworks testing and a site-specific Earthworks Specification will be necessary to ensure the appropriate management and reuse of the existing soils.

If significant earthworks are required, the works may be Category 2 in accordance with BS EN ISO 1997-1 (EC 7) and further geotechnical design may be necessary. Once site proposals have been further defined more specific consideration will need to be given to the reuse of materials and reference should be made back to this office.

6.3 Foundation recommendations

This section provides recommendations for the foundations for house terraces and apartment block as indicated on the proposed development layout (HTA Design LLP Drawing RBC-DDR-HTA-A_DR_0100 Rev C), is presented in Appendix A.

The recommendations in this report are based on the current NHBC Standards (2023).

The houses and apartment block proposed for the site could be considered to Geotechnical Category 1. However, the presence of dissolution features needs to be proved/disproved with further investigation and so are considered to be Geotechnical Category 2 at this time.

Preliminary foundation recommendations for the foundations for houses and related buildings in this section are based on the geotechnical parameters provided in Section 5.

The safe bearing pressures for foundations quoted in this report take into consideration traditional factors of safety against the risk of shear failure of the ground and should prevent undue or excessive total and differential settlement from the anticipated structural loadings.

In accordance with EC7, BS EN 1997-1+A1 (2013) the house terrace which intersects DP5 are considered to be Geotechnical Category 2 up until the point of which DP4 proves better ground conditions. Recommendations for Geotechnical Category 2 structures are presented to aid development proposals only. A separate geotechnical design will be required at the design stage.

Subject to detailed geotechnical design, the safe bearing pressures for foundations in this report take into consideration the risk of shear failure of the ground (ultimate limit state). However, they do not assess acceptable limits of settlement (serviceability limit state). Serviceability limit state assessment will need to be undertaken as part of the separate geotechnical design.

6.3.1 Foundation types

On the basis of the ground conditions indicated from the current investigation, the foundations recommended are as follows:

Table 6.1: Foundation summary

Zone	Area of the site	Recommended foundation type	Comments
A	Apartment block and houses.	Strip/trench fill	The shallow soils comprise loose to medium dense sands and clays (of unknown consistency). Minimum foundation depth for medium volume change potential (0.90 below final ground level). Foundation to be constructed at least 300mm below any Made Ground, and loose or soft compressible ground. Where deepening due to existing trees is required, foundation depths need to be calculated from original ground level. Further investigation to be undertaken to prove ground conditions between plots.
B	Eastern half of the central terrace in the vicinity of DP5	Piles	The potential dissolution feature is infilled with loose/soft materials and is considered unsuitable as a founding stratum and should be fully penetrated by foundations. Piles should be founded a suitable depth into the underlying Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated). Further investigation to be undertaken to delineate the dissolution feature.

6.3.2 Trench fill/strip foundations

Strip or trench fill foundations are considered suitable for the apartment block and houses and should be below any Made Ground and at least 300mm into the undisturbed natural strata, which comprise medium dense (or better) sands or clays of the Lynch Hill Gravels which are present from 0.20m to 1.70m bgl across the site. The strength profile across the terraces and apartment block should be confirmed with further investigation.

A safe net bearing pressure of 200kN/m² is considered appropriate when founding in granular strata. A net safe bearing pressure of 100kN/m² is considered appropriate when founding in the clays, (firm or better) estimated from the dynamic probe logs.

If enlarging the foundations is considered (for example because loads are such that the quoted safe net bearing pressure is inadequate for a standard strip foundation up to 1.0m wide) this could lead to increased settlements and the above recommendations should be reviewed.

Based on the NHBC volume change potential of medium, the minimum founding depth for strip or trench fill foundations is 0.90m below final ground level, and 0.30m below the base of the Made Ground,

In addition, the foundations may need to be further deepened to below the depth of influence of trees from desiccation effects and roots.

Where foundation depths are stepped, for instance to match changes in depths due to trees or changes in ground conditions, the steps should be designed in accordance with the requirements of the NHBC Standards.

If trees are to be removed, the roots should be grubbed out and foundations extended to below the zone of disturbance created by this activity and to below any remaining root hairs. In addition, deepening of foundations in accordance with NHBC Standards will be required where strip or trench fill foundations are within the zone of influence of existing, removed or proposed trees and proposed shrub planting. A tree survey should be undertaken by an arboriculturist in accordance with BS 5837:2012 to identify the type, and height of existing trees on the site and including any off-site trees, which could have an effect on foundation design.

Where foundations are within the zone of potential desiccation from trees and are deeper than 1.5m bgl, a suitable compressible material or void former will be required on the inside faces of foundations to external walls and beneath ground bearing floor slabs.

Foundation formations should be inspected by a geotechnical engineer or other suitably competent person to ensure the founding conditions are suitable and as indicated in this report. This should include a check for evidence of potential solution features. Any formation materials deemed as unsuitable should be excavated and replaced with lean mix concrete or deepened to suitable strata. If this is not possible, alternative solutions (such as piling) should be undertaken.

As the ground conditions at formation level are likely to be of variable type and stiffness, it is recommended that foundation concrete should be reinforced with mesh, installed at the top and bottom of the foundation, across the zone of variable soil conditions.

Foundation excavations should be protected from rainfall, inflow of surface water, frost and freezing conditions. They should also be protected from drying out in hot dry weather.

Groundwater monitoring indicates a deep groundwater table. Any water that collects at the base of the foundation excavations should be removed by pumping from a sump in the base.

6.3.3 *Subsidence Risk*

Due to the solution feature identified at DP5 a piled foundation solution would need to be adopted. In regards to the risk posed to the rest of site the number of positions is limited and it is recommended that a post-demolition (site-wide) geophysical survey to manage risk of subsidence, with targeted investigation, as proven to be necessary is undertaken.

6.3.4 *Piled foundations*

Piled foundations are recommended along the eastern half of the central terrace of houses, to deepen foundations to penetrate the potential dissolution feature infilled with loose sands/soft clays. This should be confirmed with further investigation.

Depending on column loads and layouts, piles should extend through the Lynch Hill Gravel Member and Lambeth Group and to a suitable depth into the underlying Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated).

Driven or CFA piles should be suitable to support the foundations for the structures. However, the choice of piling system should be undertaken by a specialist piling Contractor and the design of piles is beyond the scope of this report. The decision on pile type and design should take into account the following factors relevant to the site:

- » Obstructions in the ground could be expected from the previous structures on site, which could cause piles to stop shallower than the design depths, or to deviate from the vertical, thereby reducing their capacity. In some circumstances, obstructions can lead to pile breakage.

- » Pile installation can create preferential pathways for the migration of contaminants to the groundwater.
- » Boring of piles through coarse soils can result in loosening of the material, with resultant risk of shaft collapse prior to concreting and reduced shaft friction.
- » Groundwater levels are 12.50m – 13.30m bgl and temporary casing is may be required for depths below this for bored piles. If CFA piles are used, concrete is placed as the auger is withdrawn, which can balance the water pressure if the operation is undertaken carefully.
- » Piles should extend a minimum of five pile diameters into the Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) to mobilise sufficient shaft friction and end-bearing resistance to carry the required loads without unacceptable settlement.
- » As the piles are to be constructed through potentially compressible soils, piles should also be designed to cater for the potential down-drag effects of negative skin friction on piles from the secondary consolidation of the infilled dissolution feature.
- » Collapse of the pile shaft can be caused by 'necking' of the pile in running sand conditions, leading to pile failure.
- » Where bored piles extend through very soft ground, bulging of the concrete can occur, leading to lateral pressure on adjacent piles.

Piles bearing in chalk should be designed adopting the parameters and recommendations provided in earlier sections of this report and CIRIA C574 (Lord et al 2002).

Driven piles in chalk may be unsuitable as the vibrations from driving can break down the structure of the chalk making it difficult to obtain a suitable 'set' to achieve the required pile safe working load.

Based on the ground model and the geotechnical parameters in 5 the initial pile capacities for a driven and CFA piles have been estimated.

Piles driven into the low-density Grade Dm chalk are estimated to provide 600 kN/m² and CFA piles bored into the low-density Grade Dm chalk to provide 600 kN/m². Based on a minimum pile diameter of 0.30m this is likely to be more than adequate for the proposed loads, however should be designed by a specialist piling contractor.

6.3.5 *Foundation works risk assessment*

A foundation works risk assessment is likely to be necessary for piling and as there is a possibility that this could lead to creation of new pathways for migration of contamination and may result in a significant increase in risk of pollution to Controlled Waters.

The foundation works risk assessment should be undertaken in accordance with the risk assessment flowchart from National Groundwater & Contaminated Land Centre Report NC/99/73 (Figure 6.1) and will need to identify what additional risks to the environment piling may introduce and, if necessary, identify mitigation measures that will need to be put in place to remove any significant adverse environmental impacts.

6.3.6 *Working platform*

A working platform will be required prior to the arrival on site of tracked piling installation plant. This should be designed and installed in accordance with BR470 (BRE 2004) based on data on the specific plant in accordance with an FPS certificate for the rig loadings.

6.4 *Ground floor slabs*

The sub surface geology is highly varied ranging from granular sands to cohesive clays with localised made ground. It may be possible to advise the floor slab solution on an individual plot basis. However, in accordance with the NHBC standards, as Made Ground greater than 600mm

thick and clay soils of medium volume change potential are present at the site, it is recommended that suspended floor slabs with a void be adopted.

Slabs without a void (ground bearing or suspended cast *in situ* onto the ground) may be used if all of the following criteria are satisfied:

- » the foundation depth (such as due to the influence of trees) is less than 1.5m;
- » any fill is suitable, well-compacted granular material and less than 600mm thick;
- » it is demonstrated that the soils are not desiccated and are at their equilibrium moisture content; and
- » ground floor construction is not undertaken when the surface soils are seasonally desiccated (i.e. during summer and autumn), unless NHBC is satisfied the soil is not desiccated.

Ground floor slabs should be designed to incorporate any gas mitigation measures that may be required, as discussed later within this report.

6.5 Roads and pavements

Based on the test results and subject to *in situ* testing during construction, it is considered likely an equilibrium CBR of 5% will be achievable over the majority of the site for the Lynch Hill Gravel Member. Due to the variable composition of the Made Ground soils it is inferred that a CBR of <2.5% would be applicable. Made Ground was encountered across the site with exception of TP1 – 2 near the north eastern site boundaries.

Proof rolling of the formation level will be required and any loose or soft spots should be removed and replaced with an engineered fill, in accordance with a suitable Specification. The formation level will also need to be protected during inclement weather from deterioration; all slopes should be trimmed to falls to shed rain water and the surface sealed to limit infiltration.

Prior to the placement of the founding materials and the construction of the road pavement, the sub-formation and formation will need to be inspected and checked in accordance with a suitable specification to ensure the ground conditions are as expected. All testing should be carried out in accordance with DMRB IAN 73/06 to confirm that the ground conditions at time of construction are consistent with the previous design parameters.

In addition, on account of the significant depth of localised Made Ground, it is considered that ground improvement will be required even if suitable CBR values exist at the surface or can be engineered by a capping layer and early consultation is recommended.

Where the CBR is found to be less than 2.5%, the sub-grade may be unsuitable for both the trafficking of site plant and as support for a permanent foundation, without improvement works being undertaken. Improvement works should be carried out in accordance with DMRB IAN 73/06 Rev 1 Chapter 5. In summary, consideration may be given to the following potential remedial techniques:

- » excavation and re-engineering or replacement of weaker soils;
- » the inclusion of geosynthetic reinforcement within the unbound layers of the capping and sub-grade;
- » where cohesive soils are present and they are deemed suitable for treatment with hydraulic binders, to employ modification and/or stabilisation techniques on the formation; and
- » where granular soils are present, de-watering and re-engineering the formation.

6.6 Drainage

Indicative infiltration rates for the ground investigation are presented in Section 5 are summarised in Appendix B.

Preliminary permeability tests, undertaken by falling head analysis are summarised in Table 5.3 and indicate permeabilities in the range of 2.39×10^{-5} - 9.15×10^{-5} m/s.

Consideration must be given to the suitability of the ground for any proposed soakaway and any detrimental effects it could have on ground conditions or the water environment, these include:

- » Groundwater a significant depth below the site (between 9.10m – 9.17m bgl.), a seasonal high groundwater table is unlikely to meet invert required of any proposed Suds;
- » The site has a solution feature present and use of shallow soakaways as a means of surface water drainage is not recommended. Alternative strategies should be sought prior to committing to discharging surface water to the ground. Concentrated flows of surface water could wash-out and/or disturb relict infill to buried solution features, which could lead to ground movements/collapse; and
- » Where Suds must be adopted, careful investigation and assessment of proposed positions should be undertaken, to ensure the risk of subsidence is acceptable.

The site is underlain by permeable soils at depth (Chalk), consideration may be given to deep borehole soakaways. As the site is underlain by Chalk, the designer should take into account the recommendations in CIRIA Report C574 with regard to the design of deep borehole soakaways. To assist with design, the following is noted:

- » the geological setting of the site means solution features cannot be ruled out and one has been noted to be present on site;
- » there are potential solution features at the site (around location DP5);
- » Two natural cavities are recorded in the broad vicinity of the site (approximately 329m and 600m north-west); and
- » the density of the Chalk can be classified as low.

6.7 Buried concrete

Based on guidelines provided in BRE Special Digest 1 (BRE 2005) and the information presented in Section 5.6.7 (Table 5.10):

All soils (Made Ground, Lynch Hill Gravel Member, Lambeth Group and Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated)) can be classified as Design Sulfate Class DS-1 and ACEC Class AC-1.

This equates to a Design Chemical Class³ of DC-1 for all soils.

The designer should check and confirm the classification of concrete using the information presented in Appendix B and Appendix C during the design.

³ The calculated ACEC class can be used in accordance with BS 8500-1+A2 (2019), Table A.9 to select the Designated Concrete (DC) class for an intended working life of 50 years. However, the designer is referred to BS 8500-1+A2 (2019), for full details and notes to Table A.9, including any Additional Protective Measures (APMs).

7. Geo-environmental assessment

7.1 Updated conceptual model

7.1.1 Updated ground model

The initial conceptual site model developed from the desk study and field reconnaissance survey detailed in the Phase 1 Desk Study has been updated using the findings of the ground investigation and is presented in Section 5. This CSM is the basis for the geo-environmental assessment presented in this section.

7.1.2 Updated exposure model

Following the ground investigation, the plausible contaminant sources, receptors and pathways identified in the preliminary geo-environmental exposure model have been updated or confirmed as follows.

7.1.2.1 Sources

No potential sources have been removed from, or added to, the exposure model.

7.1.2.2 Receptors

No potential receptors have been removed from, or added to, the exposure model.

7.1.2.3 Pathways

No pathways have been removed from, or added to, the exposure model.

Using the updated ground model and updated exposure model, generic risk assessment is undertaken as presented below.

7.2 Risk assessment approach

Using the updated CSM, a Tier 2 generic quantitative risk assessment (GQRA) for identified receptors based on all media sampled has been undertaken in accordance with the principles of LCRM.

Firstly, the risks associated with the identified potential contaminant linkages have been estimated using standardised methods (typically involving comparison of site data with published 'screening values'). Secondly, where screening values are exceeded, the result has been evaluated in an authoritative review of the findings with other pertinent information to determine whether or not the exceedance is or is not acceptable in the site-specific circumstances.

The data sets used in the assessment comprise the analytical results obtained by Soils Limited as listed in Section 5.

In cases where potentially unacceptable risks are indicated and/or the land is potentially unsuitable for its intended use, actions such as more advanced stages of risk assessment (Tier 3, detailed quantitative risk assessment [DQRA]) or remediation are proposed in Section 7.9.

7.3 Human health risk assessment

7.3.1 Soils Assessment

7.3.1.1 Generic Assessment Criteria

The soil screening values used are generic assessment criteria (GAC) (i.e. derived in accordance with Environment Agency CLEA guidance [2009] using the updated exposure model detailed in

Defra SP1010 [2014]), with the exception of published C4SLs. The term 'GAC' used in this report is inclusive of all generic soil screening values.

Based on the proposed development, the 'residential with homegrown produce' and 'public open space (residential)' CLEA land use scenarios have been adopted.

GAC are selected based on the following hierarchy:

- » Category 4 Screening Levels (C4SL), where available.
- » SoBRA Acute GAC for free cyanide, as acute dose toxicity is the primary risk driver.
- » Hydrock GAC, derived by Hydrock as detailed in Appendix D.

The results of the assessment are presented in Appendix D.

7.3.1.2 Data sets

The data set(s) used in this report is based on the conceptual site model and the proposed development, and is taken to be the entire area of the site, with the data separated into Made Ground, Topsoil and natural soils of the Lynch Hill Gravel Member.

GAC based on a soil organic matter (SOM) of 1% have been adopted for all soils based on laboratory results. Assessment sheets are presented in Appendix D.

7.3.1.3 Assessment Results

Based on individual test results that exceed the GAC, the chemicals of potential concern (CoPC) which require further assessment are summarised in Table 7.1.

Table 7.1: CoPC in soils which require further assessment (human health)

CoPC	GAC (mg/kg)	GAC Source	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples >GAC
Residential with homegrown produce						
Made Ground						
Benzo(a)pyrene	5	C4SL - CL:AIRE 2014	4	0.10	8.77	2
Benzo(b)fluoranthene	2.6	Hydrock Derived	4	0.10	10.50	2
Dibenz(ah)anthracene	0.25	Hydrock Derived	4	0.10	1.37	2
Topsoil						
Benzo(b)fluoranthene	2.6	Hydrock Derived	2	0.10	2.76	1
Dibenz(ah)anthracene	0.25	Hydrock Derived	2	0.10	0.27	1
Lynch Hill Gravel Member						
No exceedances						
Public Open Space (residential)						
Made Ground						
Benzo(b)fluoranthene	7.2	Hydrock Derived	4	0.10	10.50	2

Dibenz(ah)anthracene	0.57	Hydrock Derived	4	0.10	1.37	2
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Topsoil

No exceedances

Lynch Hill Gravel Member

No exceedances

The individual analytical results have been compared with the relevant GAC in the summary Table 7.1. From this it is noted that PAHs within the Made Ground and Topsoil exceed the GAC for Residential with plant uptake. Furthermore, PAHs within the Made Ground exceed the GAC for POS.

All samples submitted for analysis of petroleum hydrocarbons (PHCs), including the additional testing undertaken by Soils Limited, reported concentrations below the GAC and/or laboratory limit of detection.

All samples that soils Limited submitted for the analysis of PCBs reported concentrations below the laboratory limit of detection.

The phrase 'further assessment required' is used to denote soil concentrations that exceed a GAC. This does not necessarily mean that the soil is 'contaminated' or not otherwise suitable for use. The assessment and any mitigation required are to ensure the site does not pose an 'unacceptable risk' as defined under Planning and Part 2A of EPA 1990.

7.3.2 Asbestos

No visual identification of asbestos was noted during the ground investigation and asbestos fibres were not recorded during screening of soil samples at the laboratory.

It is considered that the risk of asbestos is low.

7.3.3 Risk evaluation

The screening exercise has identified PAHs in Made Ground and Topsoil at concentrations above the GAC. These are considered further here to assess if the exceedance may be acceptable with respect to the proposed development. The phrase 'further assessment' does not necessarily mean that the soil is 'contaminated' or not fit for use.

7.3.3.1 PAHs in Made Ground

Benzo(a)pyrene is present in the Made Ground with a maximum detection of 8.77mg/kg, which is a significant exceedance of the GAC (5mg/kg). This is a significant exceedance. However, does not exceed the GAC for POS.

Benzo(b)fluoranthene is present in the Made Ground with a maximum detection of 2.6mg/kg, which is a significant exceedance of the GAC (10.5mg/kg). This is a significant exceedance and also a significant exceedance in regards to POS.

Dibenz(ah)anthracene is present in the Made Ground with a maximum detection of 1.37mg/kg, which is a significant exceedance of the GAC (0.25mg/kg). This is a significant exceedance and also a significant exceedance in regards to POS.

These significant exceedances are considered to be an unacceptable risk, which requires mitigation for the proposed end use (including private gardens, landscaping and POS).

7.3.3.2 PAHs in Topsoil

One sample of Benzo(b)fluoranthene and Dibenz(ah)anthracene is present in the Topsoil, however, at levels that are marginal exceedances when compared the GAC, comprising 2.60mg/kg vs a GAC of 2.76mg/kg and 0.27mg/kg vs a GAC of 0.25mg/kg, respectively.

Furthermore, when the double ratio plots are assessed, the PAHs are likely to be derived from coal-based products, which further reduces the risk to human health. This is presented in Appendix D.

Notwithstanding this Hydrock consider that this thickness and presence of topsoil should be further investigated as the two samples may not be representative of the whole site. This would further inform the risk that may/may not be posed by the topsoil on site and its re use in gardens and POS.

7.4 Phytotoxicity risk assessment

7.4.1 Risk estimation

Priority phytotoxic chemical concentrations have been screened against published values to determine the likely risk to plant growth (phytotoxic GAC). Phytotoxic GAC based on a pH of 7% have been adopted for all soils based on laboratory results.

As with human health, individual sample test results are compared directly with the phytotoxic GAC.

Results indicate that all CoPC are below the relevant phytotoxic GAC, therefore the contaminant linkage is incomplete.

7.5 Pollution of controlled waters risk assessment

7.5.1 Risk estimation

The risks to groundwater and surface water from contaminants on site have been assessed in accordance with the Environment Agency (2006) Remedial Targets Methodology (RTM).

Site contaminant loadings are compared with relevant screening values (Water Quality Targets [WQTs]), which are linked to the CSM.

Acceptable WQT are defined for protection of human health (based on Drinking Water Standards [DWSI]) and for protection of aquatic ecosystems (Environmental Quality Standards [EQS]).

As related specifically to this site, the data are compared with criteria selected in accordance with the methodology. This methodology involves selecting which of several alternative risk scenarios apply in this case. The assessment is presented in Table 7.2 below, with the justification for the scenarios selected explained in the following text:

- » The Lambeth Group is classified as a Secondary A Aquifer and the underlying Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) as a Principal Aquifer.
- » The site is not within a SPZ and there are no active licensed groundwater abstractions within 1km of site.
- » There are no active licensed surface water abstractions or discharges within 1km of site.
- » The nearest water course in Holy Brook 500m south of the site.
- » One sample of Made Ground soils from TP4 at 1.00m bgl was submitted for leachate analysis to model the leachability.

Table 7.2: Summary of water quality risk assessment protocol

Hydrock scenario	Water body receptors	Secondary receptors	Example contaminant linkages	RTM level and data used	Water quality targets
A	Groundwater	Human health (abstraction)	Contaminants from site leach or seep into a groundwater body that is a (potential/actual) source of water for human consumption.	RTM Level 1 - leachate	DWS

Notes:

Some EQS are water hardness dependent. This is measured either in the receiving surface water or in groundwater (if it is part of the pathway), or is estimated from national maps.

Inland waters EQS applicable to freshwater, 'other' waters EQS applicable to coastal or transitional waters.

This table and the results of the assessment are considered as a first screening for potential risks of pollution of Controlled Waters. More specific requirements may be stipulated by the relevant Agency.

The results of the screening assessment are presented in Appendix D and are summarised in Table 7.3.

In some instances, the reporting limit (or detection limit) quoted by the laboratory may be greater than the WQT that it is being assessed against. As the current exercise is an initial screening assessment, further assessment of these elements has not been undertaken.

Table 7.3: CoPC which require further assessment (controlled waters)

CoPC	WQT (µg/l)	Basis for WQT	No. samples	No. samples above LoD	Min. (µg/l)	Max. (µg/l)	No. samples exceeding WQT and above LoD
Soil Leachate Data – Made Ground							

No Exceedances

7.5.2 Risk evaluation

The DWS are not exceeded and no further assessment is required.

7.6 Ground gases risk assessment

CL:AIRE RB17 (Card et al 2012) states that where there are natural soils with low organic content and 1m to 5m of Made Ground (average <3m) that comprises general infill and car park construction materials with a TOC less than 1%, no gas protection is required as this represents CS1.

TOC data is not available; however, the Made Ground is not considered to be organic rich and the anthropogenic elements (brick, concrete, etc.) are inert. It is considered that supplementing the ground investigation data with three rounds of ground gas monitoring is suitable to confirm the risk.

7.6.1 Data

Three readings have been undertaken, however do not include during periods of falling and low atmospheric pressure. Due to the negligible risk these are considered appropriate to confirm the risk of ground gases.

7.6.2 Assessment

The risks associated with the ground gases methane (CH₄) and carbon dioxide (CO₂) have been assessed using BS 8485:2015 +A1:2019, which cites the guidelines published by CIRIA (C655, 2007) (known as Situation A).

The assessment guidelines set out in Table 2 of BS 8485 are based on interpretation of the gas concentrations and the gas flow rates. The quantitative assessment has been carried out by comparing the individual gas concentrations and gas screening values (GSV⁴) in Appendix D with the published CS thresholds (BS 8485 Table 2), in addition to a worst-case GSV assessment in accordance with section 6.3.7 of BS 8485. The assessment is summarised in Table 7.4 and the full assessment is presented in Appendix B.

Table 7.4: Ground gas risk assessment

	Min	Max	Typical ⁽ⁱ⁾	Comment
Steady Flow Rate (L/hr)	0.0	0.0	<0.01	-
Methane (%)	0.0	0.0	<1	Concentrations of Methane are below 1% and carbon dioxide is typically below 5%.
Carbon Dioxide (%)	0.0	3.5	<5	
Oxygen (%)	16.1	21.0		-
Carbon Dioxide GSV (L/hr)	0.0	0.0	<0.07	CS1
Methane GSV (L/hr)	0.0	0.0	<0.07	CS1

⁽ⁱ⁾ Hydrock assume that values are considered to be atypical if 95% or more of the remaining data are less than the value under consideration

As indicated in Table 7.4, the computed GSV for carbon dioxide and methane indicates CS1 conditions and methane and carbon dioxide at concentrations are 'typically' below 1%. As such, the site is classified as Characteristic Situation 1 (Situation A).

Based on the data no mitigation measures are required.

7.7 Construction materials risk assessment

7.7.1 Water pipelines

A formal water pipe investigation and risk assessment is beyond the scope of this report. However, the findings of this investigation have been compared to the threshold values in Water UK HBF (2014), Table 1 as far as is practicable.

The site is brownfield. However, the investigation has not detected organic contamination in exceedance of the threshold values and Hydrock believes standard pipework may be suitable for

⁴ Note: GSV is synonymous with 'site characteristic hazardous gas flow rate' (Q_{hgs}) of BS 8485:2015 +A1:2019 Table.

the site. However, confirmation should be sought from the water supply company at the earliest opportunity.

7.7.2 Other construction materials

Plastic pipes for drains and sewers are manufactured from unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) or polyethylene (PE). These materials may be affected by the presence of organic compounds in the soil.

In accordance with the British Plastics Federation Guidance (August, 2018), as the concentrations of PAH, and BTEX are below 100mg/kg and the concentrations of petroleum hydrocarbons (TPH) are below 200 mg/kg, PVC-U, PP or PE pipework is considered suitable.

The implications for buried concrete are discussed in Section 6.7.

7.8 Findings of the generic contamination risk assessments

A summary of the Source-Pathway-Receptor (SPR) contaminant linkages for which the risks may be unacceptable and require mitigation (those that are moderate or higher) are discussed in Table 7.5.

Table 7.5: Residual risks following risk evaluation

Contaminant Linkage				Comments	
Pollutant Linkage	Sources	Pathways	Receptors	General	Mitigation
PL 1.	Pervasive PAHs the Made Ground.	Ingestion, inhalation or direct contact.	Human health.	Significant exceedance of the GAC.	Mitigation required in the form of an engineered cover system.
PL 2.	Fly-tipped waste, potentially including asbestos containing materials.	Inhalation	Site users and neighbours	Fly-tipped waste has been observed on site.	This material should be removed prior to construction and appropriately disposed of.
PL 3.	PAHs within the Topsoil.	Ingestion, inhalation or direct contact.	Human health.	Lack of data and understanding of the topsoil present on site.	Further investigation and testing to be undertaken.

7.9 Mitigation measures

The outline remediation strategy presented below is provided for guidance only, and does not represent a 'Remediation Options Appraisal', or a 'Remediation Strategy', prepared in accordance with LCRM (2021).

As shown in Table 7.5 (and subject to regulatory (and NHBC) agreement), Hydrock consider the following mitigation is required to ensure the site is suitable for use for the proposed end use. The mitigation measures include:

- » The installation of a 600mm engineered cover system in gardens and POS comprising a bonded geogrid break layer (e.g. TX160G), subsoil beneath a topsoil thickness of between 150mm and 300mm (PL1).
- » Fly-tipped waste to be removed prior to construction and appropriately disposed of (PL2).
- » Further investigation and testing of the topsoil to be undertaken to inform risk and potential re-use on site (PL3).

The methodology for the remediation should be set out in a Remediation Strategy (which will include the 'Implementation Plan', the 'Verification Plan' and the 'Long Term Monitoring and Maintenance Plan'), which will need to be submitted to the warranty provider and the regulatory authorities for approval.

In addition, the production of a Materials Management Plan and its approval by a Qualified Person will be required to allow reuse of suitable material at the site in accordance with waste regulations.

Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works (including ground gas membrane installation).

8. Waste and materials management

8.1 Introduction

The Waste Framework Directive (WFD) (2009/98/EC) defines waste as '*any substance which the holder discards or intends to discard.*' In a geo-environmental context, the waste is most often 'soil' and the two main scenarios are offsite disposal of the material as a waste and/or reuse of the material on site. For cost and sustainability reasons, reuse is preferred to off-site disposal.

Section 8.2 below describes the key issues relating to off-site disposal to landfill and Section 8.3 considers requirements relating to reuse of soils and materials management.

8.2 Waste disposal

8.2.1 Principles

Based on the WFD, any material excavated on site may be classified as waste and it is the responsibility of the producer of a material to determine whether or not it is waste. Where off-site disposal is undertaken, the following guidance applies.

Classification is a staged process:

- » A hazardous waste is defined under the WFD as one which possesses one or more of fifteen defined hazardous properties. If a waste is not defined as hazardous, then it is non-hazardous.
- » Where the materials are soil, it is then be assigned using the 'List of Waste Codes', which classifies the material as either:
 - » hazardous (17-05-03), which is defined as "*soil and stones containing hazardous substances*"; or
 - » non-hazardous (17-05-04), which is defined as "*soil and stones other than those mentioned in 17-05-03*".
 - » Hydrock utilise the proprietary assessment tool, HazWasteOnline™ to undertake this assessment.
- » Waste Acceptance Criteria (WAC) testing is then undertaken if required, and are only applicable following classification of the waste, and only where the waste is destined for disposal to landfill. The WAC are both qualitative and quantitative. The WAC and the associated laboratory analyses (leaching tests) are not suitable for use in the determination of whether a waste is hazardous or non-hazardous.

It should be noted that some non-hazardous wastes may be suitable for disposal at an inert landfill as non-hazardous waste, subject to meeting the appropriate waste acceptance criteria.

It should be noted that classification must be undertaken on the waste produced, by the waste producer. Necessary sampling frequency to adequately characterise a soil population is defined within WM3.

Further discussion with regards to the characterisation process for different scenarios and waste types is provided below.

Topsoil and Peat

Topsoil and peat are biodegradable, therefore if they are surplus to requirements and cannot be re-used in accordance with a Materials Management Plan, they cannot be classified as inert. As such, topsoil and peat need to be classified by a staged assessment and sampling process and would either be classified as hazardous or non-hazardous, depending upon the results of the assessment.

Greenfield sites

Waste from completely greenfield sites may be accepted at a landfill as inert waste if it meets the requirements of paragraph 10 (wastes acceptable without testing at landfills for inert waste) of the Landfill (England and Wales) (Amendment) Regulations (2005) ('the Regulations') can be met. Paragraph 10 of the Regulations states, "*soils may be able to be classified as inert waste without testing, if:*

- » *they are single stream waste of a single waste type;*
- » *there is no suspicion of contamination and they do not contain other material or substances such as metals, asbestos, plastics, chemicals, etc...."*

As such, where the site is greenfield and the waste producer is confident about the quality of a soil (i.e. naturally occurring and uncontaminated), further sampling and laboratory testing is not necessary for the Basic Characterisation and this can be undertaken on qualitative Waste Acceptance Criteria testing.

In this instance the waste producer can characterise the waste based on visual assessment and written description of the waste in addition to supporting evidence such as a desk study assessment of the greenfield status. However, it should be noted this characterisation is subject to agreement by the landfill operator who may require testing to be undertaken to confirm classification.

Contaminated or potentially contaminated sites

If the site is brownfield, contaminated or potentially contaminated, the waste must undergo an initial waste classification exercise using background information on the source and origin of the waste and assessment of chemical test data in accordance with Environment Agency Technical Guidance WM3.

If following the initial waste classification exercise, the soils are acceptable for disposal to a non-hazardous landfill, further qualitative Waste Acceptance Criteria (WAC) testing is not required.

However, if soils are potentially able to be disposed to an inert landfill as non-hazardous waste, or require testing to determine if they can be disposed of to a stable non-reactive hazardous or hazardous class of landfill, the next stage of assessment is to undertake qualitative WAC testing. This will determine the Basic Characterisation and the landfill category at which the soils can be accepted.

Hazardous material must be subjected to WAC testing to determine whether it requires treatment before it can be accepted at the hazardous landfill, while non-hazardous material can be tested to determine whether it may be suitable for placement in an inert landfill.

8.2.2 HazWasteOnline™ assessment

As the site is brownfield, in order to inform the preliminary waste characterisation process, Hydrock has undertaken an exercise using the proprietary web-based tool HazWasteOnline™. The output of the HazWasteOnline™ assessment is provided in Appendix F and a summary of the preliminary waste classification is provided below in Section 8.2.4.

8.2.3 WAC testing

The site is brownfield and the qualitative WAC tests are provided in Appendix F a summary of the preliminary waste disposal options is provided below in Section 8.2.4.

8.2.4 Preliminary waste disposal options

The site is brownfield and based on the site history, WAC testing and the HazWasteOnline™ assessment, if suitable segregation of different types of waste is put in place, for soils to be disposed of, it is considered that:

- » The Topsoil is likely to be classified as non-hazardous waste and subject to WAC testing may be able to be disposed of at an inert landfill.
- » The natural uncontaminated subsoils are likely to be classified as 'inert' waste and based on the WAC testing should be able to be disposed of at an inert landfill.
- » The Made Ground is likely to be classified as non-hazardous waste and subject to WAC testing may be able to be disposed of at an inert landfill.
- » Any soils containing > 0.1% asbestos or visible asbestos containing materials would be considered as hazardous.

8.2.5 General waste comments

It should be noted that:

- » It is the waste producer's responsibility to segregate the waste at source and waste producers must not mix waste materials/streams or dilute hazardous components, for example by mixing with less or non-hazardous waste on site to meet WAC limit values.
- » The above preliminary assessment has been made on the basis of the soils tested as part of the ground investigation, using WAC testing and the HazWasteOnline™ assessment. However, the formal classification of waste can only be undertaken on the material to be disposed of, and by the waste producer and the receiving landfill as license conditions vary from landfill to landfill.
- » Basic Characterisation should be undertaken in accordance with Environment Agency guidance by the waste producer. Hydrock can assist if required and this report will assist the characterisation. However, Basic Characterisation does not form part of the current commission and would require further assessment and testing on the wastes actually to be disposed.
- » Once the waste producer has undertaken an initial Basic Characterisation on each waste stream, they can manage the soils as part of the on-site processing programme (for example, stockpiling, treatment, screening and separation). The waste producer and landfill operator will then need to agree the suite of compliance testing for regularly generated waste to demonstrate compliance with the initial Basic Characterisation prior to disposal.
- » At the time of disposal, additional testing on the excavated soils to be disposed of, will likely be necessary.
- » Non-hazardous and hazardous soils require pre-treatment (separation, sorting and screening) prior to disposal.
- » The costs for disposal of non-hazardous and hazardous soils are significant compared to disposal of inert material.

- » In addition to disposal costs, landfill tax will be applicable. Non-hazardous and hazardous waste will generally be subject to the Standard Rate Landfill Tax. Inert or inactive waste will generally be subject to the Lower Rate Landfill Tax. The landfill tax value changes each April and can be found at <https://www.gov.uk/government/publications/rates-and-allowances-landfill-tax/landfill-tax-rates-from-1-april-2013>.
- » Before a waste producer can move waste to a landfill site for disposal, they need to check the landfill site has the appropriate permit and must have completed the following⁵:
 - » Duty of care transfer note / Hazardous Waste consignment note, including comment as to if pre-treatment has been undertaken; and
 - » Basic Characterisation of the waste, to include: description of the waste; waste code (using list of wastes); composition of the waste (by testing, if necessary) and; WAC testing (if required).

8.3 Materials management

8.3.1 Introduction

Soils that are to remain on site, should be managed and reused in accordance with a Materials Management Plan (MMP), prepared in accordance with 'The Definition of Waste: Development Industry Code of Practice', Version 2 (CL:AIRE), known as the DoWCoP. Where all aspects of the DoWCoP are followed the soils are considered not to be waste, because they were never discarded in the first place.

Version 2 of the DoWCoP clearly sets out the principles and an outline of the requirements of a MMP. The following compliance criteria must be seen to apply to the MMP for the site:

- Factor 1: Protection of human health and protection of the environment.
- Factor 2: Suitability for use, without further treatment.
- Factor 3: Certainty of Use.
- Factor 4: Fixed Quantity of Material.

The reuse of soils at sites should be considered during the planning and development design process so that compliance with issues such as fixed quantity and certainty of use clearly relate to agreed site levels. Suitability of Use is normally evident from the remediation strategy or the design statement, which form an integral part of a MMP. However, some soils may need to be tested post-excavation to prove they are suitable for use.

Once the MMP is finalised, it must be declared by a Qualified Person (QP). The Declaration is an on-line submission as part of which the QP is required to confirm that the declaration is being made before the relevant works have commenced (i.e. it is not a retrospective application).

Once all material movements have been completed in accordance with the MMP a verification report must be produced, kept for 2 years and provided to the Environment Agency on request.

It should be noted that failure to comply with the requirements of the DoWCoP when re-using materials has potentially significant consequences for the waste holder. The risk is that the reused materials are still regarded as a waste that has been illegally deposited. From 1 April 2018, the scope of Landfill Tax has been extended to sites operating without the appropriate environmental disposal permit, and operators of illegal waste sites will now be liable for Landfill Tax. Further

⁵ ENVIRONMENT AGENCY. November 2010. Guidance on waste acceptance procedures and criteria. Waste acceptance at landfills. The Environment Agency.

information is available at: <https://www.gov.uk/government/publications/landfill-tax-disposals-not-made-at-landfill-sites/landfill-tax-disposals-not-made-at-landfill-sites>.

If soils are excavated and reused on sites (or moved to another site) without a MMP, exemption, or appropriate Permit in place, anyone who knowingly facilitates the disposal may be '*jointly and severally liable*' to any assessment of tax, fines or prosecution.

8.3.2 *Materials management scenarios*

The materials management scenarios present on site are discussed below.

It should be noted that more than one scenario may apply, dependent upon where the soils are proposed for reuse.

8.3.2.1 *Clean, naturally occurring materials – reused on the site of origin*

Where soils are naturally occurring, uncontaminated and are reused on the site they are excavated (i.e. greenfield site with documented site history, with no Made Ground), they will fall outside the Waste Framework Directive (WFD) (i.e. they will not be a waste when reused on the site of origin).

However, there needs to be certainty of that reuse, and evidence is necessary to support this strategy, for example through information provided during the planning process. The onus is on the developer to demonstrate that the materials are not a waste and will never become a waste. As such, a Materials Re-use Strategy is recommended to show certainty. Alternatively, if the volume of material is under 1,000 tonnes, then a U1 waste exemption may be applied for from the Environment Agency.

It may be noted that some 'clean naturally occurring materials' may still fail the 'suitable for use' test, for example, soils with a naturally high organic content may not be suitable for use because of their propensity to produce ground gases such as methane. Rules regarding other more unusual circumstances such as where natural soils contain an unacceptably high mineral content are described in the DoWCoP.

8.3.2.2 *Clean, naturally occurring materials – transferred to other sites*

Where soils are naturally occurring, uncontaminated and are transferred to other sites (i.e. direct transfer), they will not become waste as long as the transfer is undertaken in accordance with the DoWCoP. A MMP must be prepared for the receiving site and the materials movement must be noted in the MMP of the Donor site. This movement must have been declared to CL:AIRE prior to the works commencing.

8.3.2.3 *Made Ground and other contaminated soils*

On sites where Made Ground or contaminated soils are present, any soils excavated will be a waste as soon as they are excavated (even if they are clean, naturally occurring materials), unless they are subject to reuse in accordance with the DoWCoP. As such, for any brownfield site or a site where Made Ground is present and soils are being moved and reused, the materials could be deemed a waste, subject to either:

- a Materials Management Plan (MMP), to prevent the material being classified as a waste following reuse; or
- an exemption (for limited volumes); or
- an environmental permit, dependant on its status.

Other commonly occurring circumstances are:

If Made Ground is being moved between sites, it must be ensured that appropriate permits are in place to ensure the soils are not classified as a waste. Made Ground cannot be moved between sites under DoWCoP alone and would require relevant permits as part of the MMP documentation for the Hub site the material is being treated at.

8.3.2.4 Made Ground and other contaminated soils

All recycled materials (6F2 etc.) must be produced under the 2013 WRAP 'Quality Protocol: Aggregates from inert waste', whether on site or off-site. If they are not, they will be deemed a waste and can only be used on site under a permit. More information can be found at <https://www.gov.uk/government/publications/quality-protocol-production-of-aggregates-from-inert-waste>.

8.3.2.5 Geotechnical improvement requirements

Construction activities carried out on uncontaminated soils solely for the purpose of improving geotechnical properties e.g. lime / cement modification, are not generally regarded as waste treatment operations and do not require a permit.

However, should processing be needed (such as screening, treatment or improvement), that would constitute a waste activity and require a mobile treatment permit. This may be as simple as removing oversize material with an excavator bucket, to using a riddle bucket to remove hardcore to full mechanical screening.

9. Uncertainties and limitations

9.1 Site-specific comments

Within the Soils Limited logs, the topsoil does not appear to have been differentiated from the made ground and therefore limited testing was able to be undertaken. This has resulted in an unclarified risk and ability to re-use topsoil on site. If the Made Ground samples are considered to be of 'Topsoil' this would only further increase the risk posed to human health from the PAHs present in the Made Ground soils. The topsoil should be investigated and tested as part of the future works required in order to fully characterised.

Additional probes were requested by Hydrock within the vicinity of DP5 however Soils Limited were unable to do this due to not being able to clear locations without the assistance of their specialist service clearance team. Further investigations will need to be undertaken to delineate the solution feature on site.

9.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Reading Borough Council (the Client), by e-mail dated 23 February 2023 under the terms of appointment for Hydrock, for the sole and specific use of the Client and parties commissioned by them to undertake work where reliance is placed on this report. Any third parties who use the information contained herein do so at their own risk. Hydrock shall not be responsible for any use of the report or its contents for any purpose other than that for which it was prepared or for use of the report by any parties not defined in Hydrock's appointment.

This report details the findings of work carried out in April 2023. The report has been prepared by Hydrock on the basis of available information obtained during the study period. Although every reasonable effort has been made to gather all relevant information, not all potential environmental constraints or liabilities associated with the site may have been revealed.

Hydrock has used reasonable skill, care and diligence in the design of the investigation of the site and in its interpretation of the information obtained. The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes at the time of the investigation. At intermediate locations, conditions can only be inferred.

Groundwater data are only representative of the dates on which they were obtained and both levels and quality may vary.

Plans that provide assessment of foundation types and depths are indicative and subject to further design. This design should incorporate a detailed assessment of the influence of trees, influence of cut to fill proposals and geological conditions.

Unless otherwise stated, the recommendations in this report assume that ground levels will remain as existing. If there is to be any re-profiling (e.g. to create development platforms or for flood alleviation) then the recommendations may not apply.

Information provided by third parties has been used in good faith and is taken at face value; however, Hydrock cannot guarantee its accuracy or completeness.

Where the existing report prepared by others have been provided by the Client, it is assumed that these have been either commissioned by the Client, or can be assigned to the Client, and can be relied upon by Hydrock. Should this not be the case Hydrock should be informed immediately as additional work may be required. Hydrock is not responsible for any factual errors or omissions in the supplied data, or for the opinions and recommendations of others. It is possible that the conditions described may have since changed through natural processes or later activities.

The work has been carried out in general accordance with recognised best practice. Unless otherwise stated, no assessment has been made for the presence of radioactive substances or unexploded ordnance. Where the phrase 'suitable for use' is used in this report, it is in keeping with the terminology used in planning control and does not imply any specific warranty or guarantee offered by Hydrock.

The chemical analyses reported were scheduled for the purposes of risk assessment with respect to human health, plant life and controlled waters as discussed in the report. Whilst the results may be useful in applying the Hazardous Waste Assessment Methodology given in Environment Agency Technical Guidance WM3, they are not primarily intended for that purpose and additional analysis will be required at the time of disposal to fully classify waste. Discussion and comment with regards to waste classification are preliminary and do not form the requirements of 'Basic Characterisation' as required.

Assessment and testing for the presence of coal tar has only been completed at the locations of exploratory holes undertaken for risk assessment purposes. This investigation is not designed to provide a definitive assessment of the risk from coal tar, nor the waste classification for bituminous bound pavement arising at the site.

Unless otherwise stated, at the time of this investigation the future routes of water supply pipes had not been established. This investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling and chemical testing may be required at a later date once the routes of the supply pipes 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.

Whilst the preliminary risk assessment process has identified potential risks to construction workers, consideration of occupational health and safety issues is beyond the scope of this report.

The non-specialist UXO screening has been undertaken for the purposes of ground investigation only (i.e. low risk activity in accordance with CIRIA Report C681). Further assessment should be undertaken with regards to other higher risk activities e.g. construction.

Please note that notwithstanding any site observations concerning the presence or otherwise of archaeological sites, asbestos-containing materials or invasive weeds, this report does not constitute a formal survey of these potential constraints and specialist advice should be sought.

Any site boundary line depicted on plans does not imply legal ownership of land.

10. Recommendations for further work

Following the ground investigation works undertaken to date, the following further works will be required:

- » supplementary ground investigation to further define the dissolution feature (and therefore extent of piling required), and confirm whether shallow foundations are suitable for the rest of the site. It is recommended that this includes a geophysical survey of the site as well as further probing;
- » supplementary investigation and testing of the topsoil on site in order to fully characterise this stratum to clarify risk to human health and determine suitability for re-use;
- » discussion and agreement with utility providers regarding the materials suitable for pipework;
- » discussions with regulatory bodies and the warranty provider regarding the conclusions of this report;
- » assessment of tree influence on foundations and design of foundations;
- » discussions with piling Contractors regarding conclusions of this report and design of the piles;
- » provision of geotechnical design for the Category 2 structures (foundations) pending the results of the supplementary investigation;
- » production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider);
- » remediation and mitigation works; and
- » verification of the remediation and mitigation works.

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