PHASE 2
GROUND INVESTIGATION

Lidl Great Britain Ltd

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Remada

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795.01.01
November 2020

Client: Lidl Great Britain Ltd

Executive Summary

Remada Ltd was commissioned by Lidl Great Britain Ltd ('the client') to undertake a Phase 2 Ground Investigation for a proposed new retail store on the site of an existing Poundstretcher store at Gorseinon Road, Gorseinon, Penllergaer, Swansea SA4 9GE, at the location indicated in ***Figure 1****.*

Summary of Phase 1 Desk Study

The site occupies an approximately rectangular plot to the south of the A4240 Gorseinon Road as indicated in ***Figure 2****. The site is currently utilised by a Poundstretcher retail store of steel-framed construction, which occupies the central area of the site. A concrete surfaced service yard and greenhouse structure are located alongside the eastern and south-eastern aspect of the building. The only other structures are a water tank and plant room that are present in the south-western corner of the site. The remainder of the site is occupied by asphalt-surfaced car parking surrounding the Poundstretcher retail store.*

The earliest available historical mapping dated 1880 shows the site to be undeveloped and occupied by an area of rough pasture and heathland. Between 1964 and 1968, the majority of the site was redeveloped as a yard area associated with an off-site depot facility. Further redevelopment took place between 1982 and 1988, when the site was reprofiled in order to construct the existing retail store. This work is likely to have created thick deposits (at least 4m) of made ground underlying the western area of the site.

Published geological maps record that the site is underlain by Devensian Till, a Secondary (Undifferentiated) Aquifer and the Grovesend Formation, designated as a Secondary (A) Aquifer.

The site is located within an area which may be affected by coal mining activity. The shaft and headgear of the historic Garn-Coch Colliery No. 2 was located circa 220m to the west of the site. A Consultants Coal Mining Report was subsequently obtained from the Coal Authority, which recorded the shallowest worked seam is an 'Unnamed' seam located 159m below the site and was last mined in 1900.

The geological maps also indicate that the site is underlain by made ground classified as landscaped ground (undivided) – artificially modified ground.

Intrusive Investigation

The made ground was found to extend to depths of between 0.85m in WS1 to in excess of 4.5m in BH3. Beneath the surfacing materials the made ground was generally found to comprise soft or firm slightly sandy slightly gravelly clay sometimes with low cobble content. The gravel and cobbles comprised a mixture of quartzite, mudstone, sandstone and brick. Clinker, coal and slag fragments were also noted in some of the made ground materials.

Beneath the made ground in window sample hole WS3 a layer of wet brown fibrous peat with white rootlets was encountered between 2.9 and 3.4m. Peat was not encountered in the other exploratory holes that fully penetrated the made ground but could potentially be present in the exploratory holes that terminated within the made ground or within areas not investigated.

Beneath the made ground / peat, Glacial Till was encountered generally described as firm becoming stiff slightly gravelly sandy clay with variable cobble content. Layers of clayey sand and very clayey gravel were also encountered. The Glacial Till extended to depths of between 8.8 and 8.9m bgl beneath which stiff to very stiff clay with mudstone lithorelicts interpreted as weathered Grovesend Formation bedrock

Human Health Assessment

The results of soil chemical analysis were compared to Human Health Generic Assessment Criteria for commercial land use. None of the analytes tested were detected at concentrations that exceeded the human health GAC protective of on-site workers.

Water Resources Assessment

Concentrations of copper and zinc were identified in made ground sampled from WS5 at 0.8m slightly above what is normally typical of made ground. In addition, detectable concentrations of TPH and PAHs were encountered in some samples. Given that the site is of low sensitivity and the contaminants identified are of low solubility and mobility the risk to groundwater beneath the site is considered to be low. In addition, it should be noted that the site will be predominantly covered with the building and areas of hardstanding. Therefore, the risk of leaching of contaminants as a result of infiltration of groundwater is likely to be limited. Therefore, the risk to groundwater from contaminants within the made ground at the site is considered to be very low and does not warrant further consideration.

Waste Classification

In general, the results of the chemical analysis indicates that the made ground analysed from WS4 and WS5 would both be classified as hazardous waste based upon concentrations of zinc and TPH. The remainder of the samples would be classified as non hazardous waste. While Waste Acceptance Criteria (WAC) analysis has not been undertaken, the assessment has included determination of the fraction of organic carbon (foc). Two of the three samples classified as non hazardous exceeded this limit for disposal in an inert landfill and therefore the waste should be classified as non hazardous. WAC sampling will be required to enable disposal of hazardous waste to landfill.

Two sample of bituminous surfacing from BH1 and BH2 were analysed for concentrations of PAH compounds. The results indicate that the concentrations of PAHs were low (total PAH 17 concentration being <2.0mg/kg) and the concentration of benzo(a)pyrene of <0.1mg/kg was below the 50mg/kg limit defined in WM3. Therefore, the bituminous surfacing represented by these samples would be classified as non-hazardous waste and assigned the List of Wastes code 17 03 02 for bituminous mixtures other than those mentioned in 17 03 01.

Geotechnical Assessment

The made ground and peat encountered beneath the site will not form a suitable bearing stratum for the proposed development and structural loads will need to be transferred to competent strata beneath the Alluvium. The investigation undertaken to date has not proved the full thickness of the Alluvium and therefore the depth to competent strata is currently not known.

Consideration could be given to utilsing ground improvement techniques. However, the low strength of the made ground and peat could restrict the types of ground improvement that are suitable/viable for the site.

Alternatively consideration could be given to a piled foundation solution which could comprise either driven or continuous flight auger (CFA) piles could be utilised. The Glacial Till was found to be variable and therefore it is recommended that piles end bear within the underlying bedrock..

Given the presence of deep made ground and peat it is considered that floor slabs would either need to be fully suspended or ground improvement/piling undertaken to enable a ground bearing slab to be constructed

A Design Sulphate Class DS-2 is considered appropriate for buried concrete and an ACEC Class of AC-2 is considered appropriate for the location.

Ground Gas

The results of four rounds of gas monitoring visits placed the site into Characteristic Situation 2 and therefore ground gas protection measures will be required within the proposed buildings.

TABLES

GRAPHS

FIGURES

EXPLORATORY LOGS

APPENDICES

Issue No /	*Date*	*Prepared By*	*Technical Review*	*Authorised*
01	*26.11.2020*	*P Dickinson*	*P Welburn*	*G Jones*

1 INTRODUCTION

Remada Ltd was commissioned by Lidl Great Britain Ltd ('the client') to undertake a Phase 2 Ground Investigation for a proposed new retail store on the site of an existing Poundstretcher store at Gorseinon Road, Gorseinon, Penllergaer, Swansea SA4 9GE, at the location indicated in **Figure 1**.

1.1 Objectives

The objectives of this assessment are as follows:

- to examine whether there have been any potentially contaminative uses on the site or nearby land;
- to develop a conceptual model of the site to identify plausible pollutant linkages;
- to assess ground conditions in relation to the proposed development in relation to construction design issues including the presence, nature, likely severity and extent of soil and groundwater contamination, which may be present, its potential environmental impact and likely requirement for further work; and
- Provide preliminary foundation design recommendations for the proposed development.

1.2 Scope of Work

The scope of the investigation is generally in accordance with BS10175:2011+A2 2017 and layout of this report has been designed with the Environment Agency's CLR11[(1)] in mind and guidance issued by the Environment Agency for land contamination reports.

The scope of work comprised:

- 3 No cable percussive boreholes to target depths of 10m including SPTs;
- 5 No window sample boreholes to target depths of 6m including SPTs;
- 3 No combined groundwater and gas monitoring standpipes installed with window sample boreholes;
- Suite of geotechnical classification tests and triaxial strength tests for pile design purposes;
- 5 No soil sample suites for chemical analysis of CLEA metals, asbestos, speciated hydrocarbons, cyanide and phenols to delineate any soil contamination;
- 4 No ground gas and groundwater monitoring visits to satisfy planning requirements; and
- Combined Factual & Interpretative Geoenvironmental Report.

1.3 Previous Reports

The following Phase 1 Desk Study had been previously prepared for the site:

- Phase 1 Site Investigation & Preliminary Risk Assessment. Remada Ltd's Report 795.01.01, issued in October 2020.

1.4 Limitations

The comments given in this report and the opinions expressed are based on the information reviewed and observations during site work. However, there may be conditions pertaining to the site that have not been disclosed by this assessment and therefore could not be taken into account.

2 SUMMARY OF PHASE 1 DESK STUDY

The Executive Summary, Conceptual Site Model and other pertinent sections presented within Remada's Phase 1 Desk Study are reproduced below:

Site Setting

The site occupies an approximately rectangular plot to the south of the A4240 Gorseinon Road as indicated in ***Figure 2****. The site is currently utilised by a Poundstretcher retail store of steel-framed construction, which occupies the central area of the site. A concrete surfaced service yard and greenhouse structure are located alongside the eastern and south-eastern aspect of the building. The only other structures are a water tank and plant room that are present in the south-western corner of the site. The remainder of the site is occupied by asphalt-surfaced car parking surrounding the Poundstretcher retail store.*

The site gently slopes towards the south-west, ranging from circa 52.7m AOD (metres above ordnance datum) in the north-eastern area to 49.8m AOD in the south-western area. The western site boundary is marked by a circa 1.5m tall grassed embankment leading down to the adjacent Lidl retail store. An embankment is also present along the northern boundary, with the adjacent A4240 roadway decreasing in height westwards; resulting in a 4m grassed slope in the north-western corner of the site. Mature shrubs and several semi-mature deciduous tree species are present around the margins of the site, including silver birch, rowan and ash varieties.

Site History

The earliest available historical mapping dated 1880 shows the site to undeveloped and occupied by an area of rough pasture and heathland. Between 1964 and 1968, the majority of the site was redeveloped as a yard area of an off-site depot facility. Further redevelopment took place between 1982 and 1988, when the site was reprofiled in order to construct the existing retail store. This work is likely to have created thick deposits (at least 4m) of made ground underlying the western area of the site.

Geological Mapping

The superficial deposits underlying the site are indicated to comprise Devensian Till. The BGS describes these deposits as typically comprising 'of a heterogenous mixture of clay, sand, gravel and boulders varying widely in size and shape'.

The bedrock underlying the site is formed of the Grovesend Formation, for which the parent unit is the Warwickshire Group. The BGS describes this Formation as typically comprising 'Predominantly argillaceous, comprising mudstones and siltstones, with well-developed coals; minor lithic ("Pennant") sandstones; locally developed red mudstones in the type area'.

Mining

The site is located within an area which may be affected by coal mining activity. The shaft and headgear of the historic Garn-Coch Colliery No. 2 was located circa 220m to the west of the site. A Consultants Coal Mining Report was subsequently obtained from the Coal Authority, which recorded the shallowest worked seam is an 'Unnamed' seam located 159m below the site and was last mined in 1900.

Environmental Risk Assessment

The desk study has identified a number of on-site and off-site potential sources of contamination that would require further investigation. The following is recommended:

- *Investigation of the lateral and vertical extent of made ground/fill beneath the proposed development;*
- *Collection of soil and groundwater samples from the areas identified above for contaminants of concern; and*
- *Ground gas monitoring.*

Geotechnical Risk Assessment

It is recommended that a ground investigation is undertaken to enable preliminary foundation design.

Potential Source Areas	Potential Contaminant of Concern	Pathways	Potential Receptor	Exposure Route (Human unless otherwise stated)	Potential Identified Linkage (unmitigated)	Findings of Ground investigation	Risk (Un-mitigated)	Proposed Remediation (Mitigation) Measures	Residual Risk Estimation
<u>On-site Sources</u> **General Made Ground** **Historical Depot** **Retail Store** ***<u>Off-site Sources</u>*** **Residential housing** **Colliery and associated infrastructure** **Unspecified Tanks** **Industrial estate including paint manufacturers, builders' merchants, MOT test centre and other automotive businesses.**	Asbestos / Metals As, Be, Cd, Cu, Cr (VI), Cr (III) Hg, Ni, Se, Va, Zn, *Boron, TPH /PAH.*	Disturbance due to construction plant causing direct contact, dusts, vapours. Direct Contact with occupants of the proposed development Inhalation of fibres / vapours / gases by occupants of proposed development Permeation of water supply pipework Leachate	Occupants of the development / building fabric Adjacent residents during construction Secondary A and B Aquifers	• Direct Soil Ingestion	• Yes	To be assessed (TBA)	Potential risk	(To be assessed (TBA)	(To be assessed (TBA)
				• Indoor Dust ingestion	• Yes	As above	Potential risk	TBA	TBA
				• Skin Contact with Soils	• Yes	As above	Potential risk	TBA	TBA
				• Skin Contact with Dust	• Yes	As above	Potential risk	TBA	TBA
				• Inhalation of Outdoor Dust	• Yes	As above	Potential risk	TBA	TBA
				• Inhalation of Outdoor Vapours	• Yes	As above	Potential risk	TBA	TBA
				• Inhalation of Indoor Vapours	• Yes	As above	Potential risk	TBA	TBA
				• Inhalation of ground gas	• Yes	As above	Potential risk	TBA	TBA
				• Inhalation of radon gas	• No	N/A	Negligible	Negligible	Negligible
				• Ingestion via permeated water supply pipework	• Yes	As above	Potential risk	TBA	TBA
				• Direct contact with Secondary (Undiff) Aquifer in Superficial Deposits	• Yes	As above	Potential risk	TBA	TBA
				• In-direct contact with Secondary (A) Aquifer in bedrock	• Yes	As above	Potential risk	TBA	TBA

Table 1: Outline Conceptual Site Model

Direct contact with subsurface soil and/or groundwater during redevelopment works are not assessed as part of the CSM. It is considered that risks to workers will be managed as part of any the redevelopment works at the site through the application of health and safety procedures, where required.

3 SITE WALKOVER

The opportunity was taken to inspect the proposed Lidl store site on 13th October 2020 by Peter Dickinson of Remada Ltd prior to the commencement of the intrusive works, as recorded in the photographs below. There were no visual or olfactory indicators of contamination.

Photo 1: View westwards from the northern boundary of the site, with the existing Lidl retail store beyond, located approximately 4m lower than the Poundstretcher store

Photo 2: View eastwards along the northern frontage of the existing Poundstretcher store. The standing water on the car park followed a prolonged period of heavy rainfall overnight.

Photo 3: View northwards showing the present entrance onto Gorseinon Road.

Photo 4: View towards the south-west along the western boundary of the site. The large on-site tank in the distance is a water-storage tank for the Poundstretcher store's sprinkler system.

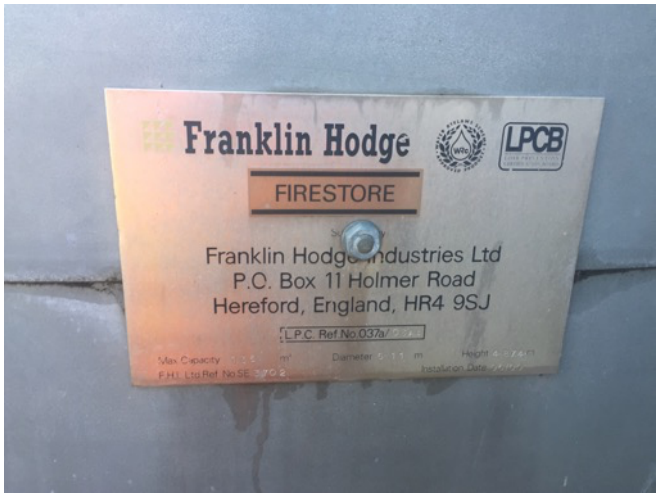


Photo 5: Detail of the maker's plate on the water storage tank.

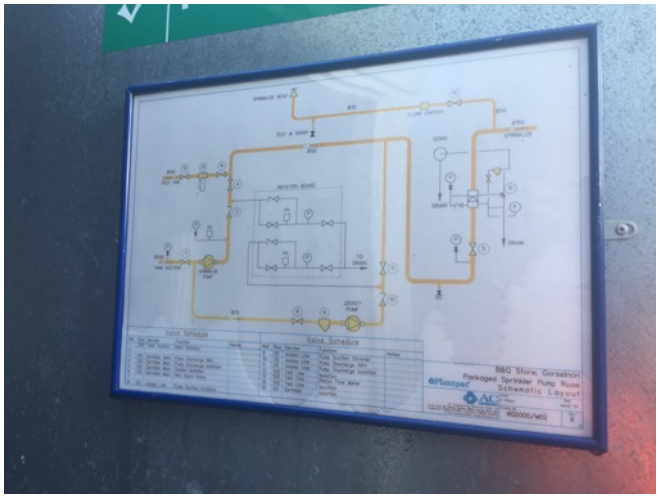


Photo 6: Detail of the sprinkler system's schematic layout drawing on display adjacent to the tank. The drawing pre-dates Poundstretcher's operations at the site and is labelled as serving the previous B&Q builders' merchants store on the site.

Photo 7: View inside the sprinkler pump room adjacent to the above ground tank in the south-western corner of the site.

Photo 8: Along the western boundary looking northwards, showing the steep embankment down from the Poundstretcher car park to the adjacent Lidl store car park. The site boundary is marked by the metal palisade fencing.

Photo 9: Interior view of the north-western corner of the existing Poundstretcher retail store, showing the steel-framed construction.

4 ENVIRONMENTAL & GEOTECHNICAL INVESTIGATION METHODOLOGY

4.1 Investigation Strategy

The A4240 Gorseinon Road adjacent to the northern boundary of the existing Poundstretcher site reduces in level from 52.8m AOD (metres above ordnance datum) in the east to circa 47m in the west. The Poundstretcher retail building and associated car park is constructed on a gently sloping plot, ranging from circa 52.7m AOD in the north-eastern area to 49.8m AOD in the south-western area. Consequently, due to the potential depth of made ground and the operational status of the Poundstretcher store, the scope of the ground investigation was varied from Lidl's standard 04.2018 to include three (3 No.) cable tool boreholes inclusive of SPTs beneath the store footprint to an anticipated depth of 10m to prove natural ground.

Remada attended site on Tuesday 13th October 2020 to undertake five (5 No.) window sample boreholes inclusive of SPTs across the site to a target depth of 6m bgl. Remada then returned to site on Monday 19th and Tuesday 20th October 2020 to undertake the three (3 No.) cable tool boreholes and to install the required ground gas / groundwater monitoring wells.

All exploratory holes were logged by a suitably qualified Geo-environmental Engineer in general accordance with the recommendations of BS5930:2015. Detailed descriptions, together with relevant comments, are given in the Exploratory Hole Logs.

4.2 Intrusive Investigation & Sampling Methodology

Cable tool holes BH1, BH2 and BH3 and window sample boreholes WS3, WS4 and WS5 were positioned within the proposed store footprint. Boreholes WS1 and WS2 were positioned within the proposed car park area.

Combined Groundwater and Ground Gas monitoring standpipes were installed in BH1, BH2 and BH3.

Standard Penetration Tests (SPTs) in the window samples were carried out at 1.0m intervals as recorded on the borehole logs to assess the relative density and consistency of soils.

SPTs were conducted in accordance with BS EN ISO 22476-3 and the recorded SPT N-values are summarised on the borehole logs and the SPT Calibration Certificates are presented at **Appendix A.**

4.3 Soil Sampling

4.3.1 Environmental

Made ground and natural soils were selected by visual and olfactory means for subsequent analysis. Samples for chemical laboratory testing purposes were collected in amber glass jars, amber glass vials and plastic tubs and retained in a cool box for transport to the laboratory.

Soil samples were scheduled for a minimum standard suite of chemical analysis that comprised quantitative asbestos, fraction of organic carbon, pH, CLEA metals, TPHCWG, PAH(16) & (17), BTEX, phenols, sulphates and chlorides.

4.3.2 Geotechnical

Geotechnical samples were collected at depths indicated on the logs with samples retrieved either from the cable percussive shell or from within a sleeve line. Disturbed samples were placed in sealed and correctly labelled plastic tubs or bags as appropriate. All geotechnical samples were dispatched to the laboratory for testing with a completed chain of custody.

Soil samples were scheduled for geotechnical classification and strength testing as appropriate to recovered soils.

4.4 Gas and Groundwater Monitoring

4.4.1 Installations

Combined ground gas and groundwater monitoring standpipes were installed in three of the window sample boreholes. The standpipes consisted of high-density polyethylene (HDPE) pipe. A bentonite seal was made around the plain pipe and a clean gravel pack was placed around the slotted pipe. A summary of the installation construction is tabulated below:

Location and Depth	Internal Diameter Pipe	Response Zone (m bgl)	Targeted Strata
BH1 – 5.0m bgl	50mm HDPE	2.0 – 5.0	MADE GROUND & Glacial Till
BH2 – 5.0m bgl	50mm HDPE	2.0 – 5.0	MADE GROUND & Glacial Till
BH3 – 4.5m bgl	50mm HDPE	1.0 – 4.5	MADE GROUND

Table 2: Monitoring Well Installation Details

4.4.2 Monitoring

Ground gas monitoring was undertaken using Geotech GA5000 gas analyser for the parameters reported below. Groundwater levels were measured with a GeoSense OWP30 oil water interface probe.

Permanent ground gas monitoring involved the measurement of the following in the prescribed order:

- Pressure difference between the monitoring well and the atmosphere,
- Peak and steady flow rates of gas into or out of the monitoring well;
- Peak and steady concentrations of carbon dioxide, methane, oxygen (minimum and steady recorded), carbon monoxide, hydrogen sulphide; and
- Depth to groundwater.

In total four monitoring visits were undertaken between 1st and 19th November 2020. The results are presented on **Table 3.**

4.5 Quality Assurance and Quality Control

All samples were submitted to a United Kingdom Accredited Laboratory (UKAS) under a completed chain of custody. The laboratory carried out its own QA/QC programme to ensure that the quality of the analytical data conformed to the appropriate test method protocols.

4.6 Laboratory Testing

4.6.1 Soil Chemical Analysis

Five (5 No) soil samples were scheduled for the analysis of asbestos, arsenic, barium, beryllium, cadmium, chromium (III & VI), copper, mercury, nickel, lead, selenium, zinc, fraction of organic carbon, Total Petroleum Hydrocarbons (TPHCWG), Polyaromatic Hydrocarbons (PAH), BTEX compounds (benzene, toluene, ethylbenzene and xylene) and phenols.

The results of laboratory chemical analyses are presented at **Appendix B.**

4.6.2 Geotechnical

Samples recovered from the boreholes were submitted to an accredited laboratory for the following analyses in general accordance with BS1377:1990:

- 5 No Natural Moisture Contents
- 5 No Plasticity Indices
- 12 No Particle Size Distribution tests;
- 7 No Quick Undrained Triaxial Compression Tests; and
- 3 No BRE SD1 suites.

The results of the geotechnical testing are presented at **Appendix C.**

5 GEOTECHNICAL & ENVIRONMENTAL INVESTIGATION FINDINGS

5.1 Ground Conditions

A summary of the ground conditions encountered during the intrusive investigation is provided below, whilst the Exploratory logs are presented at the end of the report.

In addition to the review of geological mapping that was presented in the Phase 1 Desk Study it should be noted that the geological maps also indicate that the site is underlain by made ground classified as landscaped ground (undivided) – artificially modified ground.

Landscaped ground is an area where the land surface (natural or artificial) has been extensively remodeled, but where it is impracticable or impossible to delineate separate zones of made ground, worked ground, or disturbed ground. Variable composition.

5.1.1 Made Ground

The made ground was found to extend to depths of between 0.85m in WS1 to in excess of 4.5m in BH3. WS1 was located in central part of the site but to the northeast of the other exploratory holes. The desk study indicated that the site had been historically reprofiled and as such a greater thickness of made ground was anticipated to be located in the western part of the site. This was generally confirmed by the investigation where the deepest made ground (thickness unproved) was located in the southwest of the site.

The three cable percussion boreholes were drilled in areas of asphalt surfacing which was found to be underlain by sandy gravel composed predominantly of mudstone. The five window sample holes were drilled in soft landscaped areas described slightly gravelly clay topsoil.

Beneath the surfacing materials the made ground was generally found to comprise soft or firm slightly sandy slightly gravelly clay sometimes with low cobble content. The gravel and cobbles comprised a mixture of quartzite, mudstone, sandstone and brick. Clinker, coal and slag fragments were also noted in some of the made ground materials.

5.1.2 Superficial Deposits

Beneath the made ground in window sample hole WS3 a layer of wet brown fibrous peat with white rootlets was encountered between 2.9 and 3.4m. Peat was not encountered in the other exploratory holes that fully penetrated the made ground but could potentially be present in the exploratory holes that terminated within the made ground or within areas not investigated.

In the remainder of the exploratory holes that fully penetrated the made ground and beneath the peat layer in WS3, firm becoming stiff slightly gravelly silty sandy clay with variable cobble content was encountered which occasionally included bands of medium sand. The gravel component comprised subangular to subrounded fine to coarse sandstone, limestone, quartzite and coal. This material has been interpreted as Glacial Till. It should be noted that in WS1 and WS2 the near surface clay was noted to be in a soft condition. This was confirmed by the lower recorded SPT N values and hand shear vane tests undertaken.

The Glacial Till was encountered to depths of 8.8 and 8.9m in boreholes BH1 and BH2 respectively.

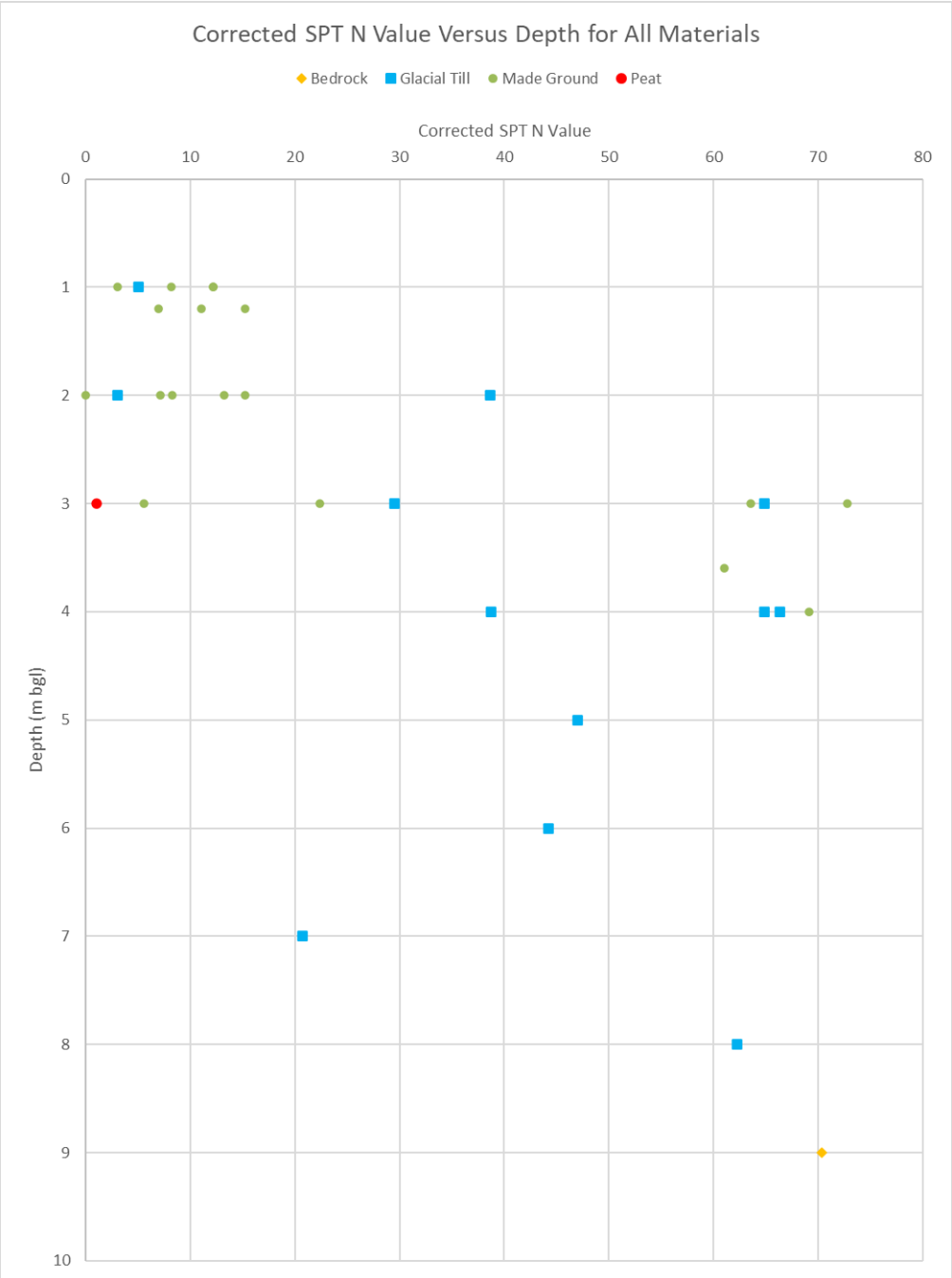
5.1.3 Bedrock

Stiff to very stiff grey mottled light brown clay with mudstone lithorelicts was encountered within the two deepest cable percussive boreholes (BH1 and BH2) at a depth of 8.8m and found to extend to 9.0m where the both boreholes were terminated. This stratum is considered to be representative of the weathered margin of the Grovesend Formation bedrock.

5.2 In-situ Testing

5.2.1 Standard Penetration Tests (SPTs)

In-situ SPTs were undertaken to assist with the interpretation of strata encountered. The SPT N-values have been corrected based on the Energy Ratio of 61% for the SPT hammer on the window sampling rig and 85% on the cable percussive rig. The SPT Hammer Energy Test Reports, undertaken in accordance with BS EN ISO 22476-3:2005 are included in **Appendix A**. The results of corrected N-values versus depth are plotted in the graph below:



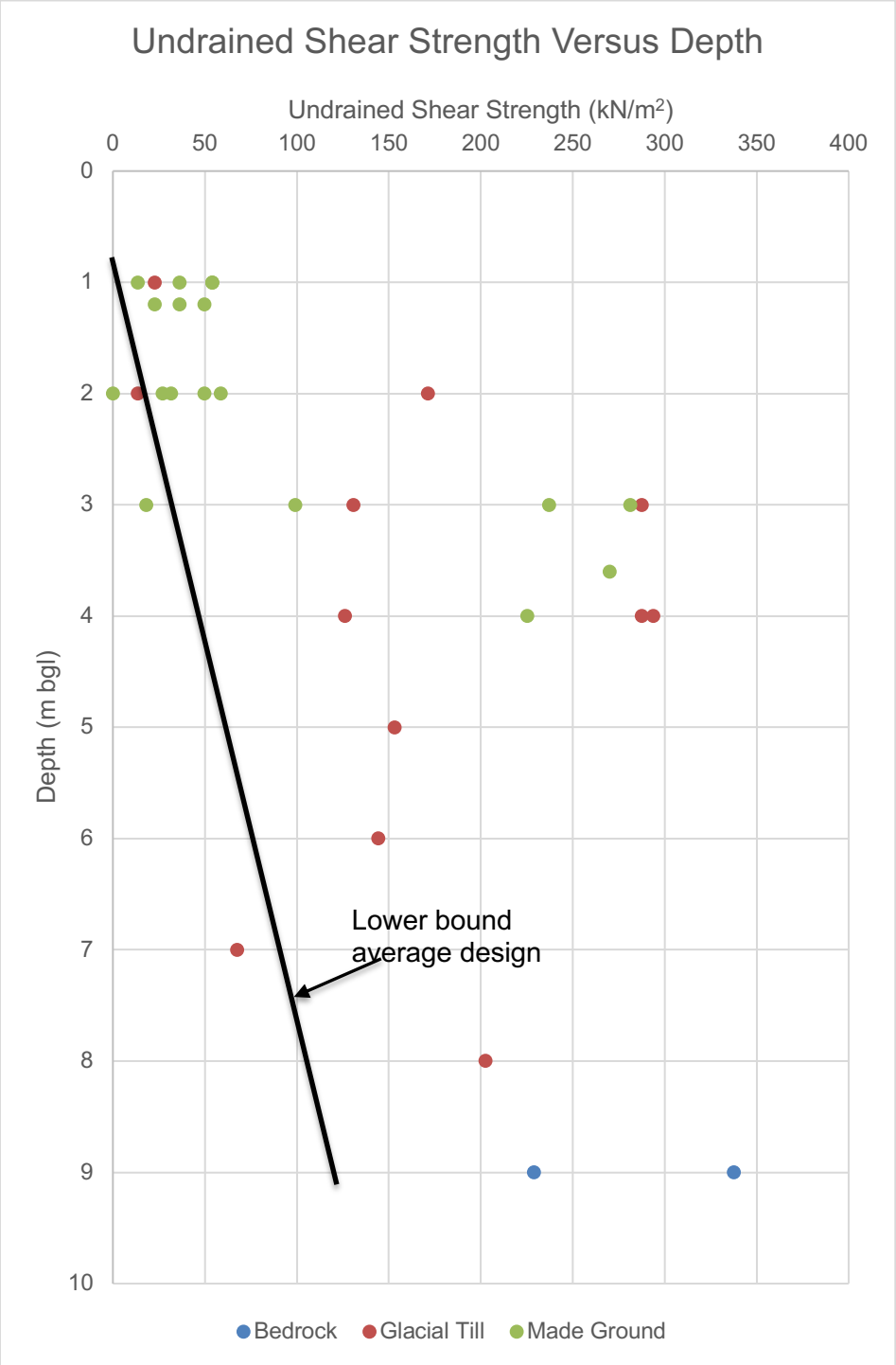
Graph 1: Plot of Corrected SPT N-Values Versus Depth

Undrained shear strengths have been estimated from SPT N values using the relationship developed by Stroud (*The standard penetration test in incentive clays and soft rocks*) and summarised in Tomlinson where:

$$\text{Mass shear strength} = f_1 \times N$$

Where f_1 is based on the plasticity index.

While the Plasticity Indices determined in the laboratory ranged from between 17 and 20%, the majority of these were samples of the near surface made ground. For this reason a slightly conservative plasticity index of 25% been assumed which equates to an f_1 factor of 4.5.



Graph 2: Plot of Mass Shear Strength Versus Depth

5.2.2 Hand Shear Vane

Twenty-two (22 No.) hand shear vane readings were successfully carried out on suitable cohesive soils (made ground and Glacial Till) recovered from the window sample boreholes. The results ranged between 18kPa (in WS4 at 0.8m) and 58kPa (in WS1 at 0.95m bgl). This is consistent with the mass shear strength results interpreted from the SPT N-values undertaken in these window sample boreholes, as demonstrated in **Graph 2**.

The use of vane shear strengths obtained from tests in confined window sample liner samples is regarded as being indicative only. Efforts were made to ensure that the sample tested was confined, i.e. the test was not performed on extruded core. However, the limitations of the testing technique are noted.

5.3 Soil Observations

Made Ground was recovered at all locations as a heterogeneous granular and cohesive material containing a variety of man-made materials including brick and clinker.

There were no visible indicators of contamination including asbestos within the sampled soils.

5.4 Groundwater Observations

Groundwater seepages were noted in the following exploratory holes:

- WS3 at approximately 3mbgl located at the interface between the made ground and the peat layer;
- WS5 at approximately 2m and 3mbgl within the made ground;
- BH1 below approximately 1.2mbgl within the made ground;
- BH2 below approximately 7.2mbgl within Glacial Till;
- BH3 below approximately 2.7mbgl within made ground.

Groundwater was found to be resting in the three monitoring wells at depths of between 1.17 and 2.72mbgl during the four monitoring visits.

5.5 Chemical Analysis

Results of the soil chemical analysis are presented in **Table 4** at the end of the report and full laboratory certificates are presented in **Appendix B**. Results of the chemical analyses are summarised as follows.

The average FOC and pH were 0.054 and 8.8 respectively. Asbestos was not detected in the samples analysed. Detectable

concentrations of metals were identified, although these are generally within the range that would typically be expected for made ground.

Concentrations of TPH were detected above method detection limit (MDL) in four of the samples analysed (all except WS5). The hydrocarbons were generally heavy end hydrocarbons within the range C16 to C35 carbon range. However, hydrocarbons in the C8 to C16 carbon range were also encountered in WS4 at 0.8 – 1.0m depth and WS3 at 0.4m. These sample was taken from made ground and there was no visual or olfactory evidence of hydrocarbon type contamination.

Total concentrations of PAHs were below method detection limit (<2 mg/kg) in the samples recovered from WS1 and WS5 only. In the other three samples analysed total PAH concentrations ranged from 53 to 140mg/kg with a maximum concentration of 140 mg/kg recorded in WS4 at 0.8 – 1.0m bgl.

5.6 Geotechnical Testing

Results of the geotechnical testing are summarised as follows and full laboratory certificates are presented in **Appendix C**.

Laboratory test results produced:

Five plasticity tests undertaken revealed, one from the natural Glacial Till and four from the cohesive made ground. The results indicated that both the natural Glacial Till and the cohesive made ground were of intermediate plasticity with plasticity indices ranging between 17 and 20%.

The PSD tests revealed the following:

- Made ground from BH1 between 0.2 and 1.2m classified the material as slightly gravelly slightly sandy clay;
- Glacial Till from BH1 between 4.0 and 4.45m classified the material as slightly sandy slightly gravelly clay;
- Glacial Till from BH1 between 6.0 and 6.45m classified the material as a slightly sandy gravelly clay;
- Glacial Till from BH1 between 8.0 and 8.45m classified the material as a slightly sandy gravelly clay;
- Grovesend Formation bedrock from BH1 between 8.8 and 9.0m was recovered as a slightly sandy gravelly clay;
- Made ground from BH2 between 2.0 and 2.45m classified the material as very clayey very sandy gravel;
- Glacial Till from BH2 between 5.0 and 5.45m classified the material as slightly sandy gravelly clay;
- Glacial Till from BH2 between 7.0 and 7.45m classified the material as very clayey very sandy gravel;
- Grovesend Formation bedrock BH2 between 8.8 and 9.0m recovered as clayey sandy gravel;
- Made ground from BH3 between 0.6 and 1.2m classified the material as slightly sandy gravelly clay;
- Made ground from BH3 between 2.5 and 3.0m classified the material as a slightly sandy gravelly clay; and
- Made ground from BH3 between 4.0 and 4.45m classified the material as a clayey sandy gravel.

Undrained shear strength tests revealed the following:

- Glacial Till in BH1 between 3.0 and 3.45m with cohesion values of 22, 27 and 31kPa for corresponding respective cell pressures of 60, 120 and 240kPa with an estimated cu value of 19kPa;
- Glacial Till in BH1 between 7.0 and 7.45m with cohesion values of 35, 45 and 53kPa for corresponding respective cell pressures of 140, 280 and 560kPa with an estimated cu value of 30kPa;
- Glacial Till in BH2 between 4.0 and 4.45m with cohesion values of 29, 36 and 41kPa for corresponding respective cell pressures of 80, 160 and 320kPa with an estimated cu value of 25kPa;
- Glacial Till in BH1 between 8.0 and 8.45m with cohesion values of 122, 140 and 167kPa for corresponding respective cell pressures of 160, 320 and 640kPa with an estimated cu value of 99kPa;

- Glacial Till in BH3 between 2.0 and 2.45m with cohesion values of 146, 177 and 226kPa for corresponding respective cell pressures of 40, 80 and 160kPa with an estimated cu value of 74kPa;

With respect to the made ground the water soluble sulphate contents varied from 110 to 150 mg/l in the three soil samples analysed with pH varying from 7.3 to 8.5. The total sulphur content varied from 0.07 to 0.12% and acid soluble sulphate varied from 0.07 to 0.11%.

5.7 Ground Gas Monitoring Results

Ground gas monitoring was undertaken on 1st, 6th, 12th and 19th November 2020 at BH1, BH2 and BH3 and are presented in **Table 3** and summarised below:

A maximum methane concentrations was recorded at a concentration of 55.2% v/v in borehole BH2 on 1st November 2020. Similarly elevated concentration were detected in BH2 during the other monitoring visits and steady concentration were only slightly lower than the peak concentration;

Carbon dioxide concentrations were recorded at a maximum concentration of 2.5% v/v in BH2 on 6th November 2020;

Oxygen concentrations were recorded at a minimum concentration of 0.1 % v/v in BH2 on 1st and 6th November 2020;

Ground gas flow rates were recorded at a maximum of 0.6 litres per hour (l/hr) in BH1 on 6th November 2020. It should be noted that groundwater level was above the screeded section of the well in borehole BH1. However, the water levels in the other wells were within the screened section and similar flow rates were detected. A maximum flow rate of 0.5% v/v was recorded in BH2, where the elevated concentrations of methane were detected.

Atmospheric pressure at the time of sampling varied between a high of 1029 millibar (mbar) on 19th November 2020 and a low of 992 mbar on 1st November 2020.

6 GENERIC QUANTITATIVE RISK ASSESSMENT

6.1 Human Health Risk Assessment

In order to provide an up to date assessment of the risks to human health, Remada has adopted the most recent Generic Assessment Criteria (GAC) published by LQM/CIEH (S4ULs) and CL:AIRE/EIC/AGS for the assessment of potential risks to human health. The derivation of GAC, methodology, input parameters and technical guidance (CLEA) may be obtained upon request.

Default parameters have been adopted for sandy loam of pH 7 and commercial land use. FOC ranged from 0.024 to 0.1 giving a Soil Organic Matter (SOM) content range of between 4.1% to 17.2% with an average result of 9.3%. In order to present a conservative assessment, the SOM content of 6% has been adopted for the assessment.

The depth to potential sources of contamination for indoor air pathways has been assumed to be 0.5m below building foundation level. The source has been conservatively assumed to be at ground level for outdoor air and direct contact pathways.

For commercial land use the CLEA version 1.06 critical receptor is conservatively modelled as a female working adult with an exposure duration of 49 years. In accordance with the default parameters it was assumed that employees spend most of their time indoors and that 80% of outdoor area is covered by hardstanding. As such, the potential exposure pathways have been assumed to be:

- Direct Soil and Indoor Dust Ingestion;
- Skin contact with soils and dusts;
- Inhalation of indoor and outdoor dusts and vapours.

Where GAC values for individual TPH fractions are not exceeded, the potential additive effect has been assessed by calculating overall TPH hazard index for each sample.

6.2 Comparison of Soil Analysis Results with Human Health GAC

A comparison of soil chemical analysis with GAC is presented as **Table 4**.

<u>TPH, PAH & BTEX</u>

None of the analytes tested were detected at concentrations that exceeded the human health GAC protective of on-site workers.

<u>Metals & Inorganics Excluding Asbestos</u>

None of the analytes tested were detected at concentrations that exceeded the human health GAC protective of on-site workers.

<u>Asbestos</u>

There was no asbestos detected in any of samples selected for analysis.

6.3 Controlled Waters Risk Assessment

The Glacial Till encountered beneath the site has been classified as a Secondary (Undifferentiated) Aquifer with the underlying bedrock classified as a Secondary A Aquifer. The site is not located within a designated Groundwater Source Protection Zone. With respect to the Glacial Till, where clay is encountered these deposits are normally considered to be Unproductive Strata with more permeable layers assigned an aquifer classification. In general the Glacial Till was found to comprise clay deposits with more granular

materials encountered at depth. It is therefore considered that the Glacial Till will provide some protection to the underlying Secondary A Aquifer within the Grovesend Formation.

The results of the soil chemical analysis undertaken has identified that concentrations of metals and inorganic contaminants were generally within the range of typical made ground, although slightly elevated concentrations of copper and zinc were identified in WS5 at 0.8m. Detectable concentrations of TPH and PAHs were encountered in some samples. The highest concentrations were detected in WS4 at 0.8m with a TPH concentration of 2,700mg/kg and total PAH concentration of 140mg/kg. There was no visual or olfactory evidence of contamination. The contaminants identified are generally of low solubility and mobility and, given that the superficial deposits were generally cohesive in nature, it is considered that the risk presented to underlying groundwater to be low. In addition, it should be noted that the site will be predominantly covered with the building and areas of hardstanding. Therefore, the risk of leaching of contaminants as a result of infiltration of rain water is likely to be limited. Therefore, the risk to groundwater from contaminants within the made ground at the site is considered to be low and does not warrant further consideration.

6.4 Ground Gas Assessment

In order to understand the gassing regime at the site, a Characteristic Situation (as defined in CIRIA C665 and BS8576:2013) is determined for the site. CIRIA C665 and BS8576 provides definitions for each Characteristic Situation based on Gas Screening Values (GSV) which are calculated as follows:

GSV = Gas Concentration (% v/v) x Measured Borehole Flow Rate (l/hr)

BS8576 makes a distinction between the GSV and the Hazardous Gas Flow Rate (Q_{hg}) which is also calculated using the above calculation. BS8576 states that Q_{hg} is calculated for each individual borehole for each monitoring visit, where as the GSV is taken as the representative value for the site or site zone.

As a worst case assessment the GSV for the site is therefore taken as the maximum carbon dioxide/methane concentration recorded in the boreholes which is multiplied by the maximum flow rate recorded during the same monitoring event.

Methane GSV = 55.2 % x 0.6 l/hr = 0.3312 l/hr.

Carbon dioxide GSV = 2.5 % x 0.6 l/hr = 0.015 l/hr

The calculated GSV for methane and carbon dioxide places the site into Characteristic Situation 2. BS8485 states that gas protection measures should be considered for the proposed development.

For a commercial building of this type (Type C) at a site classified as Characteristic Situation 2 the required minimum gas protection score for a low risk site in accordance with BS 8485:2015+A1:2019 (Table 4) is 2.5. Appropriate forms of floor and substructure designs are listed Table 5 of BS 8485:2015+A1:2019; it is likely that structural barriers, ventilation and a ground gas membrane would comprise suitable mitigation measures.

6.5 Revised Conceptual Site Model

A revised Conceptual Site Model is presented as **Table 5** below.

6.6 Waste Classification

In general, the results of the chemical analysis indicates that the made ground analysed from WS4 and WS5 would both be classified as hazardous waste based upon concentrations of zinc and TPH. The remainder of the samples would be classified as non hazardous waste. While Waste Acceptance Criteria

(WAC) analysis has not been undertaken, the assessment has included determination of the fraction of organic carbon (foc) which can be converted to TOC by multiplying the result by 100. A TOC limit of 3% is placed on waste destined for disposal in an inert landfill. Two of the three samples classified as non hazardous exceeded this limit it is considered that the waste should be classified as non hazardous. WAC testing is not required for disposal of non hazardous waste to landfill. WAC testing will be required for disposal of hazardous waste to landfill.

Two sample of bituminous surfacing from BH1 and BH2 were analysed for concentrations of PAH compounds. The results indicate that the concentrations of PAHs were low (total PAH 17 concentration being <2.0mg/kg) and the concentration of benzo(a)pyrene of <0.1mg/kg was below the 50mg/kg limit defined in WM3. Therefore, the bituminous surfacing represented by these samples would be classified as non-hazardous waste and assigned the List of Wastes code 17 03 02 for bituminous mixtures other than those mentioned in 17 03 01.

6.7 Health & Safety Considerations

To ensure direct exposure of construction workers involved in the site redevelopment to any impacted contaminated shallow soils is minimised, the guidance stated in HSG 66 “Protection of Workers and the General Public During Redevelopment of Contaminated Land” should be followed.

Potential Source Areas	Potential Contaminant of Concern	Pathways	Potential Receptor	Exposure Route (Human unless otherwise stated)	Potential Identified Linkage (unmitigated)	Findings of Ground investigation	Risk (Un-mitigated)	Proposed Remediation (Mitigation) Measures	Residual Risk Estimation
On-site Sources **General Made Ground** **Historical Depot** **Retail Store** ***Off-site Sources*** **Residential housing** **Colliery and associated infrastructure** **Unspecified Tanks** **Industrial estate including paint manufacturers, builders' merchants, MOT test centre and other automotive businesses.**	Asbestos / Metals As, Be, Cd, Cu, Cr (VI), Cr (III) Hg, Ni, Se, Va, Zn, *Boron, TPH /PAH.*	Disturbance due to construction plant causing direct contact, dusts, vapours. Direct Contact with occupants of the proposed development Inhalation of fibres / vapours / gases by occupants of proposed development Permeation of water supply pipework	Occupants of the development / building fabric Adjacent residents during construction	• Direct Soil Ingestion	• Yes	No exceedance of GAC	Very Low	Hardstanding cover to minimise direct contact	Negligible
				• Indoor Dust ingestion	• Yes	As above	Very Low	As above	Negligible
				• Skin Contact with Soils	• Yes	As above	Very Low	As above	Negligible
				• Skin Contact with Dust	• Yes	As above	Very Low	As above	Negligible
				• Inhalation of Outdoor Dust	• Yes	As above	Very Low	As above	Negligible
				• Inhalation of Outdoor Vapours	• Yes	As above	Very Low	As above	Negligible
				• Inhalation of Indoor Vapours	• Yes	As above	Negligible	N/A	Negligible
				• Inhalation of ground gas	• Yes	CS2	Low risk	Gas protection measures to be installed	Negligible
				• Inhalation of radon gas	• No	N/A	Negligible	Negligible	Negligible
				• Ingestion via permeated water supply pipework	• Yes	Potential for permeation	Potential risk	Contaminant resistant piping may be required in some areas	Negligible
		Leachate	Secondary A and B Aquifers	• Leaching to Secondary (Undifferentiated) and Secondary (A) Aquifer in bedrock	• Yes	Contaminants generally of low solubility and mobility	Low	Hardstanding to prevent precipitation infiltration and leaching	Very low

Table 5: Refined Conceptual Site Model

Direct contact with subsurface soil and/or groundwater during redevelopment works are not assessed as part of the CSM. It is considered that risks to workers will be managed as part of any the redevelopment works at the site through the application of health and safety procedures, where required.

6 GEOTECHNICAL SITE ASSESSMENT

6.1 Geotechnical Considerations

An indicative site layout is indicated in **Figure 2** with the existing store located in the central part of the site. The proposed Lidl store to be located in the western third of the site with associated car parking located to the east as shown in **Figure 3.** Along the northern and western boundaries of the site there are existing embankments and these are to be retained. It is understood that finished levels will be similar to existing

Exploratory holes BH1, BH2, WS2 to WS5 are all located within the proposed store footprint with borehole BH3 located a short distance to the east. The investigation has identified that beneath the store footprint the made ground extended to depths of between 2.1m to in excess of 4.5m. In general the made ground appeared to be deepest in the southwest. It should also be noted that peat was identified in WS3 between 2.9 and 3.4mbgl.

Beneath the made ground and peat the Glacial Till was encountered to a proved depth of 8.9 and 8.8mbgl in borehole BH1 and BH2 respectively. The Glacial Till was generally firm to stiff but was found to be softened in some locations.

Details of the proposed permanent and variable design loads (actions) are not currently known although an indicative column load of 400kN has been provided.

6.2 Foundations

Due to the presence of deep made ground underlain in some locations by peat, Lidl preferred raft foundation is not considered suitable for this site. In addition, pad foundations are unlikely to be viable given that foundation depths in excess of 4.5m would be required.

Ground improvement techniques such as vibro-replacement stone or concrete columns could be considered for the site. Both ground improvement techniques involve inserting a vibrating poker into the ground, which displaces the soil. The resultant void is then infilled with either stone or concrete. Vibro-replacement stone columns may not be suitable for the site as the soft made ground and peat layers may not provide the lateral support required and the stone may spread laterally over time. However, vibro-replacement concrete columns can be installed in weaker soils. In order for concrete columns to work effectively they will need to penetrate the full thickness of the made ground and peat. Therefore a column depth in the order of 5 to 6mbgl should be anticipated. It should be noted that a number of the exploratory holes terminated within the made ground and therefore the potential for deeper made ground to be present should not be ruled out. The proposed Lidl store also coincides with the existing building footprint and therefore it will be necessary to remove foundations associated with the existing structure prior to installation of the stone or concrete columns.

It is recommended that specialist advice is sought from a ground improvement contractor with regard to the suitability of this technique in these ground conditions and the anticipated achievable bearing capacities. If either of these techniques is selected, it is recommended that appropriate in-situ testing is specified in order to assess the performance of these foundations.

If a piled foundation solution is adopted then either driven or continuous flight auger (CFA) piles could be utilised. Driven piles have the advantage of improving the density of the ground whereas CFA piles could potentially loosen the granular deposits and thus result in a reduced safe working load. The main disadvantage of driven piles is that they can cause unacceptable amounts of vibration that could potentially damage nearby above and underground structures. If driven piles are used then assurances will need to be sought from the piling contractor that damage will not be caused to nearby structures, including buried infrastructure on the site.

While the undrained shear strength estimated from SPT N values for the Glacial Till below approximately 5m was generally in excess of 100kPa, the results of the laboratory analysis indicated that there were weaker zones present. This could either be due to presence of softer zones or layers with a reduced proportion of fines (clay and silt). Given this variability it is recommended that piles end bear within the more consistent bedrock.

Remada has undertaken a preliminary assessment of potential safe working loads for pile design based upon the following idealised soil profile based on the intrusive work and the following assumptions:

Depth (m)	Ground Conditions	Assumptions
GL to 5.0	Made Ground and Peat	Ignored in calculations – Made ground proved to 4.5m depth, assumed to extend to 5m in calculations.
5.0 to 8.9	Superficial Deposits: Glacial Till	Assume cohesive for purposes of calculations although, in some cases was borderline between exhibiting cohesive and granular behaviors. N values and cu values taken from Remada's design line as shown on Graph 2 as follows: • Average cu value of 100kN/m^2 taken at 7m depth.
>8.9	Bedrock	Assumed to comprise very stiff clay with cu=200kN/m^2

Table 6: Idealised Soil Profile for Preliminary Pile Assessment

Groundwater has been assumed to be at >6mbgl.

The following table provides a summary of the estimated safe working loads base on the assumptions detailed above:

Pile Toe Depth (m)	Pile Type	Pile Diameter (mm)	Estimated Safe Working Load (kN)
10	CFA	300	190
10	CFA	450	325
10	CFA	600	490
10	Driven	300	195
10	Driven	450	320
10	Driven	600	495

Table 7: Estimated Safe Working Loads

The safe working load has been calculated by two different methods. In the first method a factor of safety of 2.5 is applied to both the end bearing and skin friction components. In the second method a factor of safety of 3.0 is applied to the end bearing component and 1.5 to the skin friction component. The safe working load is calculated by both methods and the lower of the two adopted.

The above table indicates that piles are likely to require installation into bedrock (as assumed for the piles end bearing at 10m bgl). Piles should be driven a minimum of 9 pile diameters into the bearing stratum.

The estimated safe working load is indicative only and specialist piling contractors should be consulted with regard to the design and performance of their piled foundations. As discussed above further investigation will be required in order to prove ground conditions below 6m depth.

The calculated safe working load has been calculated for a single isolated pile. The effect of group action has not been taken into consideration. In addition, negative skin friction in the made ground have not been taken into consideration.

It should be noted that the depth to bedrock may vary across the site and therefore, piles of differing lengths are likely to be required. If driven piles are adopted then provisions should be made to enable pile lengths to be easily varied. In addition, several of the exploratory holes encountered obstructions within the made ground. Provision should be allowed for pre-probing of pile locations.

6.3 Floor Slab

Given the presence of deep made ground and very soft/soft Alluvium it is considered that floor slabs would either need to be fully suspended or ground improvement/piling undertaken to enable a ground bearing slab to be constructed.

6.4 Excavations and Temporary Works

Side slopes within the Made Ground and any underlying natural superficial deposits are unlikely to remain stable even in the short term without support or without being battered back to a safe slope gradient. A detailed inspection of the side slopes should be made during excavation and a risk assessment carried out to fully assess the support measures required.

Groundwater was found to be resting within the three monitoring wells at depths of between 1.17 and 2.72mbgl.

6.5 External Car Park Construction

The road pavement is likely to be constructed on a subgrade of either made ground. The made ground on site is likely to be variable and for preliminary design purposes is considered to have a CBR of 2%.

It is recommended that once the site has been graded to the appropriate pavement formation level, it is inspected and, if necessary, in situ CBR testing be conducted on the subgrade to confirm the appropriate pavement design (i.e. to determine the subbase and capping thickness).

6.6 Protection of Buried Concrete

In accordance with BRE SD1 for buried concrete in a brownfield site with mobile groundwater, analyses of selected samples of made ground for water soluble sulphate returned values of up to 0.15 g/l and pH >7.3. A total potential sulphate value of 0.36% was also calculated from the total sulphur results. Therefore a Design Sulphate Class DS-2 is considered appropriate for buried concrete and an ACEC Class of AC-2 is considered appropriate for materials that have the potential to become oxygenated during the development.

6.7 General Construction Advice

Where applicable ground beneath the proposed building footprint and potentially car parking may require to be stripped to reveal localised areas of made ground and structures. Excavations should be backfilled with suitably re-compacted materials to achieve formation level.

Foundations associated with the existing structure will need to be removed prior to redevelopment of the site.

7 CONCLUSIONS & RECOMENDATIONS

7.1 Conclusions

The following conclusions have been made based on the findings of this investigation.

7.1.1 Phase 2 Site Investigation

The earliest available historical mapping dated 1880 shows the site to be undeveloped and occupied by an area of rough pasture and heathland. Between 1964 and 1968, the majority of the site was redeveloped as a yard area associated with an off-site depot facility. Further redevelopment took place between 1982 and 1988, when the site was reprofiled in order to construct the existing retail store. This work is likely to have created thick deposits (at least 4m) of made ground underlying the western area of the site.

The made ground was found to extend to depths of between 0.85m in WS1 to in excess of 4.5m in BH3. Beneath the surfacing materials the made ground was generally found to comprise soft or firm slightly sandy slightly gravelly clay sometimes with low cobble content. The gravel and cobbles comprised a mixture of quartzite, mudstone, sandstone and brick. Clinker, coal and slag fragments were also noted in some of the made ground materials.

Beneath the made ground in window sample hole WS3 a layer of wet brown fibrous peat with white rootlets was encountered between 2.9 and 3.4m. Peat was not encountered in the other exploratory holes that fully penetrated the made ground but could potentially be present in the exploratory holes that terminated within the made ground or within areas not investigated.

Beneath the made ground / peat, Glacial Till was encountered generally described as firm becoming stiff slightly gravelly sandy clay with variable cobble content. Layers of clayey sand and very clayey gravel were also encountered. The Glacial Till extended to depths of between 8.8 and 8.9m bgl beneath which stiff to very stiff clay with mudstone lithorelicts interpreted as weathered Grovesend Formation bedrock.

7.1.2 Human Health Risk Assessment Retail Zone

The results of soil chemical analysis were compared to Human Health Generic Assessment Criteria for commercial land use. None of the analytes tested were detected at concentrations that exceeded the human health GAC protective of on-site workers.

7.1.3 Water Resources Risk Assessment

Concentrations of copper and zinc were identified in made ground sampled from WS5 at 0.8m slightly above what is normally typical of made ground. In addition, detectable concentrations of TPH and PAHs were encountered in some samples. Given that the site is of low sensitivity and the contaminants identified are of low solubility and mobility the risk to groundwater beneath the site is considered to be low. In addition, it should be noted that the site will be predominantly covered with the building and areas of hardstanding. Therefore, the risk of leaching of contaminants as a result of infiltration of groundwater is likely to be limited. Therefore, the risk to groundwater from contaminants within the made ground at the site is considered to be very low and does not warrant further consideration.

7.1.4 Waste Classification

In general, the results of the chemical analysis indicates that the made ground analysed from WS4 and WS5 would both be classified as hazardous waste based upon concentrations of zinc and TPH. The remainder of the samples would be classified as non hazardous waste. While Waste Acceptance Criteria (WAC) analysis has not been undertaken, the assessment has included determination of the fraction of organic carbon (foc). Two of the three samples classified as non hazardous exceeded this limit for disposal in an inert landfill and therefore the waste should be classified as non hazardous. WAC sampling will be required to enable disposal of hazardous waste to landfill.

Two sample of bituminous surfacing from BH1 and BH2 were analysed for concentrations of PAH compounds. The results indicate that the concentrations of PAHs were low (total PAH 17 concentration being <2.0mg/kg) and the concentration of benzo(a)pyrene of <0.1mg/kg was below the 50mg/kg limit defined in WM3. Therefore, the bituminous surfacing represented by these samples would be classified as non-hazardous waste and assigned the List of Wastes code 17 03 02 for bituminous mixtures other than those mentioned in 17 03 01.

7.2 Geotechnical Recommendations

The made ground and peat encountered beneath the site will not form a suitable bearing stratum for the proposed development and structural loads will need to be transferred to competent strata beneath the Alluvium. The investigation undertaken to date has not proved the full thickness of the Alluvium and therefore the depth to competent strata is currently not known.

Consideration could be given to utilsing ground improvement techniques. However, the low strength of the made ground and peat could restrict the types of ground improvement that are suitable/viable for the site.

Alternatively consideration could be given to a piled foundation solution which could comprise either driven or continuous flight auger (CFA) piles could be utilised. The Glacial Till was found to be variable and therefore it is recommended that piles end bear within the underlying bedrock..

Given the presence of deep made ground and peat it is considered that floor slabs would either need to be fully suspended or ground improvement/piling undertaken to enable a ground bearing slab to be constructed

A Design Sulphate Class DS-2 is considered appropriate for buried concrete and an ACEC Class of AC-2 is considered appropriate for the location.

7.3 Ground Gas

The results of four rounds of gas monitoring visits placed the site into Characteristic Situation 2 and therefore ground gas protection measures will be required within the proposed buildings.

REFERENCES & GUIDANCE

AGS, Guidance on the Waste Classification for Soils – A Practitioners' Guide 2019.

Barnes, G. 2010, Soil Mechanics Principles and Practice. 3rd Edition.

BRE, Special Digest 1:2005 (3rd Edition), Concrete in Aggressive Ground. 2005.

BS 10175:2011+A1:2013, Investigation of potentially contaminated sites: Code of practice.

BS 1377:1999. Methods of test for soils for civil engineering purposes.

BS 5930:2015, Code of practice for site investigations.

BS 8485:2015, Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

BS 8576:2013, Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).

BS EN ISO 22476-3:2005, Geotechnical investigation and testing: Field testing - Standard penetration test.

CIRIA, C504, Engineering in glacial tills, 1999.

CIRIA, C665, Assessing risks posed by hazardous ground gases to buildings, 2007.

CIRIA, C682, The VOCs Handbook: Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination, 2009.

CIRIA, C716, Remediating and mitigating risks from volatile organic compound (VOC) vapours from land affected by contamination, 2012.

CIRIA C733, Asbestos in Soil and Made Ground: A Guide to Understanding & Managing Risks.

CL:AIRE/EIC/AGS, The Soil Generic Assessment Criteria for Human Health Risk Assessment, 2009.

CL:AIRE, SP1010, Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination -Final Project Report. 2013.

CL:AIRE, The Definition of Waste: Development Industry Code of Practice Version 2

DEFRA, Circular 01/2006, Contaminated Land Environmental Protection Act 1990, Part 2A. 2006.

DEFRA, SP1010, Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Policy Companion Document. March 2014.

Environment Agency, Model Procedures for the Management of Land Contamination, CLR 11, 2004.

Environment Agency, Verification of Remediation of Land Contamination Science Report – NC/00/38/SR

Environment Agency, Waste Classification, Guidance on the classification and assessment of waste (1st Edition V1.1) Technical Guidance WM3.

Health & Safety Executive, HSG 66, Protection of Workers and the General Public During Redevelopment of Contaminated Land. 1991.

Highways Agency, IAN 73/06 Rev 1, Design of Pavement Foundations, 2009.

LCM/CIEH, The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, S4UL3146, 2015.

NHBC Standards, 2019.

Tomlinson, M.J., 2001, Foundation Design and Construction, 7th Edition.

The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

STUDY LIMITATIONS

IMPORTANT. This section should be read before reliance is placed on any of the information, opinions, advice, recommendations or conclusions contained in this report.

1. This report has been prepared by Remada, Ltd with all reasonable skill, care and diligence within the terms of the Appointment and with the resources and manpower agreed with (the 'Client'). Remada does not accept responsibility for any matters outside the agreed scope.

2. This report has been prepared for the sole benefit of the Client unless agreed otherwise in writing.

3. Unless stated otherwise, no consultations with authorities or funders or other interested third parties have been carried out. Remada is unable to give categorical assurance that the findings will be accepted by these third parties as such bodies may have published, more stringent objectives. Further work may be required by these parties.

4. All work carried out in preparing this report has used, and is based on, Remada' professional knowledge and understanding of current relevant legislation. Changes in legislation or regulatory guidance may cause the opinion or advice contained in this report to become inappropriate or incorrect. In giving opinions and advice pending changes in legislation, of which Remada is aware, have been considered. Following delivery of the report Remada has no obligation to advise the Client or any other party of such changes or their repercussions.

5. This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report.

6. Whilst this report and the opinions made are to the best of Remada' belief, Remada cannot guarantee the accuracy or completeness of any information provided by third parties.

7. This report has been prepared based on the information reasonably available during the project programme. All information relevant to the scope may not have received.

8. This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of changes in the condition of the site since the time of the investigation.

9. The content of this report represents the professional opinion of experienced environmental consultants. Remada does not provide specialist legal or other professional advice. The advice of other professionals may be required.

10. Where intrusive investigation techniques have been employed they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature of sampling, no investigation technique is capable of identifying all conditions present in all areas. In some cases the investigation is further limited by site operations, underground obstructions and above ground structures. Unless otherwise stated, areas beyond the boundary of the site have not been investigated.

11. If below ground intrusive investigations have been conducted as part of the scope, service tracing for safe location of exploratory holes has been carried out. The location of underground services shown on any drawing in this report has been determined by visual observations and electromagnetic techniques. No guarantee can be given that all services have been identified. Additional services, structures or other below ground obstructions, not indicated on the drawing, may be present on site.

12. Unless otherwise stated the report provides no comment on the nature of building materials, operational integrity of the facility or on any regulatory compliance issues.

13. Unless otherwise stated, samples from the site (soil, groundwater, building fabric or other samples) have NOT been analysed or assessed for waste classification purposes.

TABLES

FIGURES

EXPLORATORY LOGS

APPENDIX A
SPT Calibration Certificates

APPENDIX B
Laboratory Chemical Analysis

APPENDIX C
Laboratory Geotechnical Tests