Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

St Mary The Virgin School, Cardiff

Proposed New School & Nursery

Exploratory Geoenvironmental and Geotechnical Assessment

Report Reference: ESP.7048b.02.3208 Rev1

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Proposed School and Nursery
Exploratory Geotechnical & Geo-environmental Assessment

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Executive Summary

Cardiff County Council (hereafter known as the Client) are proposing to redevelop the subject site with a new school, nursery and associated external areas. ESP have undertaken an exploratory geo-environmental and geotechnical assessment, comprising a review of desk study and previous intrusive investigation data, supplementary investigation works, laboratory testing and assessment of data. This report includes the Preliminary Risk Assessment and Generic Quantitative Risk Assessment (for human health and controlled waters) elements of CLR11. The key potential land quality issues identified by the assessment are summarised below:

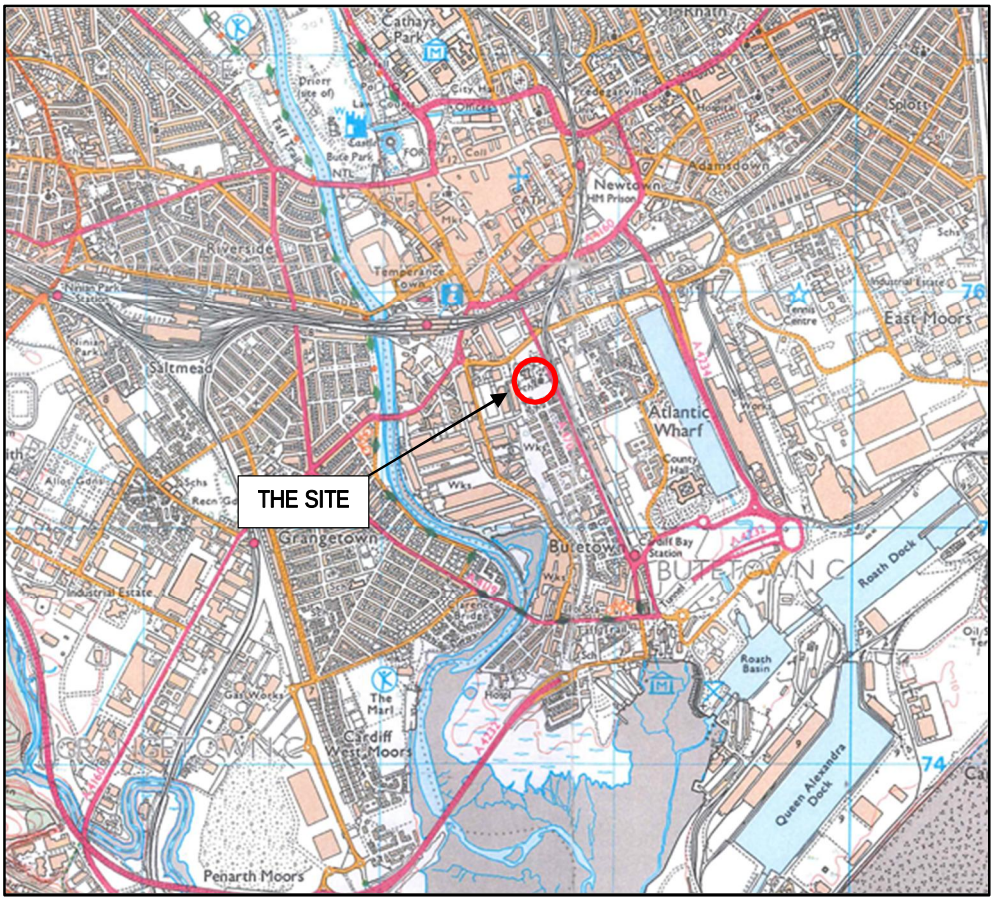
	Potential Hazard	Anticipated Risk	Discussion
Site Setting	*Current Site Status.*	-	*The site is currently occupied by playing fields associated with the St Marys the Virgin Primary School site.*
	Identified Ground Conditions.	-	*The investigation has indicated a cover of Made Ground over Tidal Flat Deposits, Fluvioglacial Deposits and Mercia Mudstone bedrock. .*
	Groundwater Conditions.	-	*The site is underlain by a Secondary Aquifer. Groundwater was not encountered during the investigation.*
	Historical Land Use.	-	*The site has been indicated as open fields and extensive residential housing with a number of local historical land uses.*
Geo-environmental	*Potential Contamination Sources*	*High*	*Potentially contaminative land uses including timber yards, dock construction, works and canals.*
	Chronic Risks to Human Health	*Moderate/Low*	*Most of the determinants analysed were below. their respective GAC however, lead requires further consideration. Soils unlikely to be suitable for planting.*
	Risks to Controlled Waters	*Low*	*Generally low risk anticipated. .*
	Hazardous Ground Gas	*Moderate*	*Ground gas protection measures are likely to be required and this will be assessed upon completion of gas monitoring.*
	Other Hazards	*Low*	*No Asbestos identified in soil samples analysed.*
Geotechnical	*Weak/Compressible Ground, requiring non-traditional foundations.*	*Moderate*	*On the basis of the available investigation data the use of conventional shallow foundations on the near surface Made Ground cannot be recommended due to the possible occurrence of insufficient bearing capacity and unacceptable differential settlements.*
	Sulphate Attack on Buried Concrete	*Low*	*Generally low levels identified.*
	Other Hazards	*Moderate*	*Underground structures attributed to historic buildings likely to be present within the Made Ground. Services including a large brick culvert present on site.*
Others	*UXO*	*Low*	*Preliminary UXO risk assessment indicates detailed UXO study is essential.*
	Invasive Plants	-	*None identified during site walkovers.*
	Further Investigation Required?	*Yes*	*See Section 8.0 for requirements.*

Note: The above is intended to provide a brief summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

1 Introduction

1.1 Background

Cardiff County Council (hereafter known as the Client) are proposing to redevelop the subject site with a new school, nursery and associated external areas. The Earth Science Partnership Ltd (ESP), were instructed by the Client, to undertake an exploratory geotechnical and geo-environmental investigation and assessment to identify and evaluate potential ground hazards which could impact on the proposed development. The site location is shown below on Insert 1.



Insert 1: *Site Location Plan from Ordnance Survey 1:20,000 (OS License No.: AL100015788).*

The proposed development will comprise a three storey school, single storey nursery, possible community café, MUGA pitch and associated external areas of hardstanding, parking and landscaping. We understand that no significant changes to the current ground levels are proposed.

The proposed site layout is presented as Figure 1 in the enclosures. Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2015).

A previously undertaken Desk Study and limited infiltration assessment phase of works were undertaken by ESP in November and December 2018 (Ref: 7048b.3095 and 7048b.3105 respectively) and have been summarised where pertinent throughout this report and provided in full in as Appendices B and C.

1.2 Objective and Scope of Works

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the site, potential risks posed by contamination and ground gas, and to allow an assessment of these ground conditions with particular reference to the potential impact on the proposed development.

We are not aware of any ground hazard related planning conditions relating to the development at present.

The scope of works for the investigation was developed with the Client by ESP within an agreed budget, and comprised a review of all previous information, a contemporary field reconnaissance visit, the supervision and direction of windowless samples, light cable percussion boreholes, geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health, controlled waters, and reporting.

The contract was awarded on the basis of a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 21st November 2018 (Ref: 7048b.02.lt1). Due to accessing restrictions and undertaking of other inspections on site, the works have been undertaken between January and April 2019 with assessment and reporting undertaken in May 2019.

1.3 Report Format

This report includes the previous desk study and field reconnaissance reports (Section 2), and details of the investigation undertaken of BS5930:2015 (Section 3), along with the Preliminary Risk Assessment and Generic Quantitative Risk Assessment. A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included.

A preliminary risk register, identifying potential geotechnical hazards is presented as Section 2.9, with a full assessment of the geotechnical conditions including foundation and floor slab options, the feasibility of soakaways, etc. in Section 7 – this complies the relevant elements of the Geotechnical Design Report of BS EN 1997-2 and BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment and the report concludes with a summary of any further surveys/ investigations/ assessments recommended.

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Section 3.2.1 and in Appendix A.

1.4 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a

comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.5 Digital Copy of Report

This report is issued as a digital version only.

2 Summary of Previous Desk Study Information

The information presented in this section comprises a summary of the previous ESP report (Ref: 7048b.3095) with the full report presented in Appendix B.

2.1 Site Location and Description

The site is located in the south east of Cardiff, near Atlantic Wharf. The National Grid Reference of the centre of the site is (ST) 318676E 175564N and the approximate postcode is CF10 5HG. A Site Location Plan is presented as Figure 1. The site comprises a roughly 'L' shaped parcel of land of around 100m length (west to east) at it longest point and 50m width (north to south) occupying an area of around 0.9Ha and is situated at an elevation of around 10mAOD, however, we have not been provided a formal topographic survey at this time. The site is situated in a densely urbanised area of Cardiff Bay, with a mix of residential/retail/commercial properties and infrastructure surrounding. It is presently undeveloped area and bounded by:

- To the north: immediately by St Mary The Virgin Church and an existing primary school, followed by commercial areas.
- To the east: immediately by the Bute Street, followed by residential areas and Atlantic Wharf approximately 700m to the east.
- To the south: immediately by commercial and industrial areas, with Cardiff Bay some 1.5km to the south.
- To the west: Immediately by commercial buildings, followed by residential areas.

The site is currently undeveloped and laid to grass with low level fencing on two sides of the site, with and existing buildings forming the boundaries on the remaining two sites. The west portion of the site is segregated by a low level wooden fence.

2.2 Site History

As part of the preliminary assessment, the site history was assessed from a review of available historical Ordnance Survey County Series and National Grid maps. The information from the historical mapping is summarised in Table 1 below and included in Appendix B.

Table 1: Review of Historical Mapping

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1879-1947	The site is indicated to be fully covered with residential buildings and associated access roads.	The site is located in the centre of a residential areas that is bordered by a highly industrialised zone. A church is present at the north boundary. The Glamorganshire Canal and associated wharves, are indicated approximately 20m to the west of the site followed by a timber yard and associated timber pond. A series of railways and foundry's are indicated further south. The River Taff and associated salt marshes are indicated approximately 500m to the west. A railway is indicated at the east boundary, followed by a series of works comprising wire rope manufacture, engineering services, flour mills, timber yards and warehousing.

		The Bute West Dock, is identified approximately 250m to the east. Significant rail infrastructure is indicated beyond the west dock leading to the Bute East Dock, some 500m to the east. The main Great Western Railway line with associated sidings, stations and good sheds is indicated approximately 250m to the north.
1953 – 1964	No significant changes are indicated.	The canal to the west is indicated to be disused and partially infilled. A series of engineering works and factories are indicated at the west boundary. An abattoir is indicated approximately 150m to the west.
1964 – 1969	The site is now indicated to vacant, with all buildings demolished, however, the previously existing roads are still indicated.	The canal to the west is now indicated to be fully infilled. No other significant changes are indicated.
1974 - 1995	No significant changes are indicated.	The timber pond to the west and the Bute West Dock are both indicated to have been infilled, with rough/marshy ground indicated. Engineering works and other structures are indicated to fully occupy the timber pond site and partially occupy the dock. St Mary The Virgin Primary School is indicated to the north. Realignment works along the River Taff (to the west) are noted during this period.
2002 - 2014	The site remains vacant and no other significant changes are indicated.	Significant development has occurred around the site, with the majority of the industry not identified but know to comprise, works, factories and warehousing. Significant residential development has occurred on the location of the former Bute West Dock alongside the construction of Lloyd George Avenue linking Cardiff City to Cardiff Bay. All rail infrastructure historically present to the west and east is no longer indicated but remains to the north.

2.3 Site Geology

2.3.1 Published Geology

The published geological map for the area of the site (1:10,000 scale, ST17SE) indicates the site to be underlain by Made Ground, followed by Tidal Flat Deposits overlying bedrock of the Mercia Mudstone Group.

Based on the information obtained, the historical map assessment and knowledge of the surrounding area, we anticipate the site will have a significant covering of Made Ground, especially where there has been demolition of buildings and subsequent re-development such as the construction of previously occupying buildings and the development and infilling of the Timber Pond, Glamorganshire Canal, and Docks.

The Tidal Flat superficial strata would be expected to be fine-grained in nature with some coarse bands and will also likely contain a high proportion of organic materials. The Mercia Mudstone Group bedrock comprises red, less commonly green-grey, mudstones and subordinate siltstones. Thin beds of gypsum/anhydrite can be widespread; sandstones are also present.

2.3.2 Identified Geology

The exploratory site works have undertaken as part of the infiltration testing assessment (Ref: 7048b.3105) identified a ground model comprising Made Ground over Tidal Flat Deposits and Glaciofluvial Deposits.

2.4 Geoenvironmental Risk Evaluation & Relevant Pollutant Linkages

2.4.1 Introduction to Risk Evaluation Methodology

The methodology set out in CIRIA C552 *Contaminated Land Risk Assessment – A Guide to Good Practice* (Rudland et al, 2001), has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk. The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (Table A1 in Appendix A):
- The magnitude of the probability (likelihood) of risk occurring (Table A2 in Appendix A).

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category (Tables A3 and A4 in Appendix A). These tables have been revised slightly from those presented in CIRIA C552, to allow for the circumstances where no plausible linkage has been identified and, therefore, no risk would exist.

The methodology described above has been used to establish Plausible Pollutant Linkages (PPL) based on the Conceptual Site Model generated for the site and proposed development, and to evaluate the risks posed by those linkages.

This was then updated in our previous report with geoenvironmental report, using information obtained from the site during the intrusive investigation and assessment. Table 3 below presents the plausible pollutant linkages from our previous assessment.

Table 2: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL) – ESP Report 7048b.3095, Table 4, Section 3.2.2

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils from general Made Ground and previous on site land uses (former buildings etc) and encroachment of off site uses (railways, infilled timber pond, canal, dock etc.).	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users	Medium – potential for chronic levels.	High likelihood[2]	Moderate/High Risk	Sampling of near-surface soils to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High likelihood[2]	Moderate Risk	Likely to be managed with PPE however, sampling of near-surface soils to confirm levels of total contamination present.
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary Aquifer	Low likelihood[2]	Moderate/High Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
Asbestos in shallow soils.	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	High Likelihood[3]	Moderate/High Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[4]	Moderate Risk	Sampling of soils to confirm levels of sulphate, pH, and groundwater.
Hazardous ground gas/vapours from on and offsite sources including infilled timber pond, canal, docks etc. (see Section 3.1.4).	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors	Severe – acute risk.	High likelihood[5]	**High Risk**	Install and monitor gas wells.
	Damage through explosion.	Building/Property	Severe – acute risk.		**High Risk**	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		**High Risk**	
Radon gas	Migration into Buildings	Site Users	Medium – potential for chronic levels	Unlikely[6]	Low Risk	No radon protection measures required.

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section **Error! Reference source not found.**.
2. Although Made Ground is anticipated, the presence of contamination has yet to be confirmed on site.
3. The presence of Asbestos Containing Materials or Asbestos within shallow soils has yet to be confirmed on site.
4. The Mercia Mudstone strata can potentially contain sulphates/pyrite.
5. Significant potential for on and off site ground gas sources.
6. Radon risk identified in environmental data report (Section 2.10).

2.5 Geotechnical Conditions

During the Desk Study phase of the previous assessment, a number of potential geotechnical hazards were identified. The risks posed by these hazards was assessed and are presented in Table 3 below with further information on geotechnical hazards further explained in the following sections.

Table 3: Updated Geotechnical Risk Register

Ground Stability Hazard	Potential[1]	ESP Comment
Coal Mining	Low	Site does not lie within historical coal mining area. No further information identified to contradict data report.
Mining (non-coal)	Low	Site does not lie within historical non coal mining area and no obvious quarry or other extraction features are noted on available historical information. No further information identified to contradict data report.
Shrinking or Swelling Clays	Very Low	See Section 2.5.1.
Landslides	Very Low	No further information identified to contradict data report.
Ground Dissolution (Soluble Rocks)	Negligible	No further information identified to contradict data report.
Compressible Ground	Moderate	See Section 2.5.2.
Collapsible Ground	Negligible	No further information identified to contradict data report.
Running Sand	Moderate	See Section 2.5.3.
Sulphate/Pyritic Ground	Not reported.	See Section 2.5.4.
Unexploded Ordnance	Not reported.	See Section 2.5.5.
Obstructions	Not reported.	See Section 2.5.6

Notes
1. Potential as reported in environmental data report (Appendix B)
2. Salient hazards discussed in following sections.

2.5.1 Shrinking or Swelling of Clays

The anticipated underlying Tidal Flat Deposits and upper (weathered) Mercia Mudstone may comprise soils of probable low strength and, hence, are potentially sensitive to volumetric change. Therefore, we consider that the potential for shrink/swell at the site should be advanced from that reported in the environmental data report (Table 3, Very Low) to **Moderate/High** until intrusive works are undertaken to confirm the risk.

2.5.2 Compressible Ground

The Made Ground and low strength Tidal Flat Deposits anticipated beneath the site are potentially compressible, particularly where containing organic materials are present, which could lead to significant settlement at the surface. Therefore, we consider that the potential for compressible ground at the site should be advanced from that reported in the environmental data report (Table 3, Moderate) to **Moderate/High** until intrusive works are undertaken to confirm the risk.

2.5.3 Running Sand

The Tidal Flat Deposits anticipated below the site, can commonly contain bands/lenses with a high proportion of sand, which can contain water bodies. If intercepted within the excavations, we consider that the potential for running sands beneath as reported in the environmental data report (Table 3, Moderate) is appropriate.

2.5.4 Pyritic Ground

The environmental data report does not consider the potential risk from sulphate rich or pyritic ground.

The Mudstone bedrock and anticipated Made Ground underlying the site are listed by the BRE (2005) as potentially containing elevated levels of pyrite, which may oxidise to sulphates and lead to aggressive attack on buried concrete. Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be **Moderate.**

2.5.5 Unexploded Ordnance

The environmental data report does not consider the potential risk from unexploded ordnance at the site.

A Preliminary UXO Desk Study assessment of risk is being completed in advance of site works by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and will be provided on completion, however, available mapping suggests the risk is likely to be **High** due to the proximity to the Cardiff docklands.

In the absence of a detailed assessment, all works undertaken as part of this intrusive investigation have been undertaken under the supervision of a UXO specialist.

2.5.6 Obstructions

The site has been previously developed and at one time, fully occupied by housing. There is a potential for obstructions in the form of historic foundations, basements and demolition materials. These may present a physical hazard to planned investigation works and subsequent redevelopment.

2.6 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are

naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures.

The environmental data report (Appendix B) indicates that the site does not lie in a radon affected area as defined by the Health Protection Agency, with less than 1% of properties above the Action Level, with no Radon protection measures required. Given the currently available information, the risk from radon is considered **Low**.

3 Exploratory Investigation

3.1 Investigation Points

3.1.1 Introduction

The exploratory investigation comprised a series of hand excavated Trial Pits, Windowless sample holes, Light Cable Percussion and Rotary Boreholes and was undertaken in accordance with BS5930:2015 and BS10175:2013. The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015. Descriptions and depths of the strata encountered are presented on the exploratory hole records in Appendices D and F and the exploratory hole locations are presented on Figure 2. Records for previous exploratory works such as soakaway testing, have been presented in the relevant Appendix (see Appendix C).

The ground levels and coordinates indicated on the investigation point records are approximate only and have been interpolated from the recent Ordnance Survey maps.

3.1.2 Preliminary Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2013, taking into account the additional potential for geotechnical hazards to be present.

The exploratory hole locations were spread across the site in order to maximise the information obtained whilst working around the existing buildings and other accessing restrictions on site.

3.2 Hand Excavated Trial Pits

3no. hand excavated trial pits were constructed to depths of between 0.6m and 0.7m on the 24th April 2019 in order to supplement the spatial distribution of sample locations across the site. Disturbed samples were obtained for identification and laboratory testing purposes.

3.3 Windowless Sampling

11no. windowless sample drillholes (WS01 to WS11) were constructed between the 22nd and 24th April 2019. A hydraulically powered rig was used to drive plastic lined sampling tubes into the ground, with the soil recovered within the tubes, which are then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes. The windowless sampling provided generally good recovery to the depth of refusal.

Standard Penetration Tests (SPT) were carried out in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the soils encountered in the borehole and to provide an correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

On completion, monitoring instrumentation was installed in the boreholes as detailed in Section 3.6 below.

3.4 Light Cable Percussion Boreholes

5no. 200mm diameter cable percussion boreholes (BH1 to BH5) were constructed to a maximum depth of 15m between 21st January and 31st January 2019. The borehole records are presented as Appendix E. The boreholes were progressed to rock head (encountered between 9.0m and 10.5m) to allow progression of rotary coring (see Section 3.5).

At the commencement of each borehole, a square of the grass landscaping was cut and a service inspection pit excavated by hand to a depth of 1.2m.

Standard Penetration Tests (SPT) were carried out using a split spoon and solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole and to provide an correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

On completion, the boreholes were left open and secured with heras fencing to allow for rotary follow on drilling.

3.5 Rotary Cored Drillholes

5no. rotary cored drillholes were constructed (BH1 to BH5) between 21st and 31st January 2019. Boreholes BH1 to BH5, were rotary drilling follow on from the light cable percussion boreholes. Cores of nominal 72mm diameter were recovered in plastic liners using a triple tube barrel system, over runs of nominal 1.5m length. Where recovery was poor, the core length was reduced for the next run to maximise the chances of good recovery. The recovered cores were sealed in the plastic liners and placed in solid core boxes to prevent disturbance and swelling before logging. The plastic liners were only cut immediately prior to logging and sampling. In addition to the nature of the rock material, the identified fractures within the rock mass were also logged in accordance with BS5930:2015. The Rock Quality Designation (RQD) recorded was for rock core 100mm or greater in length. The fracture state of the recovered cores is presented on the drillhole records.

On completion, instrumentation was installed in boreholes as detailed in Section 3.6. Below the instrumentation, the borehole was backfilled with bentonite and arisings. Boreholes in which monitoring installations were not constructed were backfilled with arisings, topped up with gravel where necessary and made good at the surface.

3.6 Instrumentation

3.6.1 Well Installations

A 50mm diameter monitoring well was installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases. The wells,

comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above and below the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in Table 4 below.

Table 4: Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum
WS01	24/04/2019	0.5 – 2.5m	Probable Made Ground/Tidal Flat Deposits
WS02		0.5 – 2.5m	
WS06		0.5 – 2.4m	
WS08		0.5 – 2.0m	
WS10		0.5 – 2.5m	
BH02	23/01/2019	3.0 – 10.5m	Fluvioglacial Deposits
BH04	30/01/2018	3.0 – 10.5m	
BH03	31/01/2019	3.0 – 9.0m	

3.6.2 Gas Monitoring

Monitoring of the installed gas wells is being undertaken on a 'spot' monitoring basis (periodic visits to monitor gas levels at the time of the visit). CIRIA C665 (Wilson et al, 2007) provides guidance on the number and frequency of monitoring visits required for installed gas wells. These depend on the gas generation potential of the source and the sensitivity of the development to gas risk and are designed as a typical minimum only.

To date, the installed wells have been monitored for levels of groundwater and ground gas on 4no. occasions (allowing for earlier installation of deeper wells), with a further 3no. visits planned.

During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measures levels of the following ground gases within the airspace in the wells and the flow rates from the wells:

- Methane - total and percentage of Lower Explosive limit (LEL);
- Carbon dioxide;
- Oxygen; and
- Hydrogen sulphide.

The percentage of nitrogen is also calculated by difference. The equipment uses infra-red methane (CH_4) and carbon dioxide (CO_2) detectors, coupled with pressure (barometric and well), temperature and flow sensors. A photo-ionisation detector (PID) was used during the monitoring to measure the levels of volatile organic compounds present in the well

3.7 Sampling Strategy

3.7.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed. A non-targeted, random sampling strategy was used to obtain representative information on soil contamination across the site as a whole. However, a number of constraints were imposed on the available sampling locations by existing buildings and pitches and therefore a regular grid sampling pattern could not be adopted.

Environmental samples (denoted as ES on the exploratory holes records) were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub, an amber glass jar and an amber glass vial. The sample containers provided clean by the testing laboratory appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

3.7.2 Soil Sample Quality

Samples of soil recovered from investigations are classified as Classes 1 to 5 in terms of quality and depend on the investigation and sampling method, the particle size of the strata sampled, and the presence of groundwater. Class 1 and 2 samples are those in which there has been no or only slight disturbance of the soil structure, with moisture contents and void ratios being similar to the in-situ soil. Class 3 and 4 samples contain all the constituents of the in-situ soil in their original proportions, and the soil has retained its original moisture content, but the structure of the soil has been disturbed. In Class 5 samples, the soil structure and original layering cannot be identified and the water content may have changed from that in-situ. The category and class of samples are discussed further in BS EN ISO 22476:2006, EN 1997-2:2007 and BS5930:2015.

In general terms, disturbed samples recovered from trial pits (bulk bags and small tubs) are classed as Class 3 (if dry), Class 4 (fine soil below the water table), or Class 5 (coarse soils from beneath the water table). Cutting relatively undisturbed block samples from trial pit walls provides Class 1 or 2 samples, provided that they are collected, preserved and transported in an appropriate manner.

During cable percussion drilling, samples of fine-grained soils collected using thin wall, open tube samplers (OS-T/W) are generally Class 1 samples, whist samples collected using thick wall, open tube samplers (OS-TK/W) are classed as Class 2 or 3, provided they are sealed and waxed on collection. OS-T/W (thin wall) samplers cannot be used when coarse particles are present in the soils (e.g. in glacial deposits).

The split spoon sample from a Standard Penetration Test (SPT) is usually considered a Class 5 sample however, it can be deemed Class 4 in homogeneous fine-grained soils. Disturbed sampling (bulk bags and small tubs) from boreholes is considered Class 3 (if dry), Class 4 (fine soil below the water table) or Class 5 (coarse soils from beneath the water table).

The samples recovered within the liner in windowless sampling are generally Class 3 in fine-grained soils with good recovery, becoming Class 2 in favourable circumstances, but Class 3 or 4 in coarse-grained soils.

The quality class of each sample collected as part of the investigation is shown on the exploratory hole records.

3.8 Evidence of Site Hazards Found During Site Works

With regard to potential hazards identified in the desk study and Preliminary Risk Assessment, the following observations were made.

3.8.1 Site Stability

Made Ground with likely poor in-situ strengths has been encountered across the site, underlain by Tidal Flat deposits with weak insitu strengths. The likely presence of earth basement floors has been identified at depths of around 2m.

3.8.2 Site Evidence of Contamination

No direct visual/olfactory evidence of extraordinary contamination was identified in the exploratory holes. However, Made Ground was present across the with a number of man-made materials within it, such as brick, concrete and wood fragments.

3.9 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix H.

- Natural moisture content.
- Atterberg limits.

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

The results of the sulphate testing are included with the geo-environmental test results in Appendix G.

3.10 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil and leachate generated from shallow soils.

The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Section 4.1.1). The results are presented in Appendix G.

3.10.1 Soil Samples

The PRA (Section 3.1.2) did not identify any particular contaminants of concern at the site. However, given the presence of Made Ground, in order to allow an assessment of the potential chronic risks posed to human health and have been analysed for contaminants typically found on brownfield sites in the UK. The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;

- Total cyanide;
- Asbestos qualitative screen (presence or absence);
- Soil organic content, pH value.

The geo-environmental soil test results are presented in Appendix F.

4 Development Of The Revised Conceptual Model

4.1 Geology

The exploratory holes have identified the site to be generally underlain by general Made Ground and Tidal Flat Deposits underlain by coarse Glaciofluvial Deposits, with Mercia Mudstone Group bedrock underlying the superficial soils. These strata are discussed in more detail in the following sections.

General Made Ground: generally encountered to depths of between 0.6n and 2.0m but to a maximum depth of 3.0m (in WS03 only) with variable conditions across the site. The soils comprised sandy clayey gravels, sandy gravelly clay with cobbles and clayey sands with manmade materials including brick, concrete and wood, with occasional tiles

Tidal Flat Deposits: encountered below the Made Ground and proven to depths of between 2.5m and 3.0m. The tidal flat deposits generally comprised soft and firm dark blue grey slightly gravelly silt and clay with occasional organic matter recorded throughout.

Laboratory testing within the fine-grained Tidal Flat Deposits indicated liquid limits between 48 – 58% plasticity indices between 27 and 39% and natural moisture contents between 19 – 21% The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of intermediate to high plasticity.

Glaciofluvial Deposits: encountered below the Tidal Flat Deposits and proven to dpeths of between 9.0m and 10.5m. The coarse deposits generally comprised clayey sand gravel and clayey gravel with low cobble content. The gravels were generally subangular to subrounded and fine to coarse of limestone and sandstone.

Mercia Mudstone Group Bedrock: encountered in all boreholes from depths of between 9.0m to 10.5m and 11.8m and proven to a maximum depth of 18.0m The Mercia Mudstone bedrock encountered has been most commonly classed as Class C – Partially Weathered Mercia Mudstone. The bedrock generally comprised extremely weak thickly laminated highly fractured reddish brown mudstone interbedded with occasional bands up to 200mm of stiff clay, fine to coarse gravels and bands of competent medium strong mudstone. Where more highly weathered Mercia Mudstone was encountered (Class Da and Db), the bedrock comprised non intact reddish brown very stiff thinly and thickly laminated gravelly clay. Generally the bedrock was recovered as non intact or with a fracture index of >20.

4.2 Hydrogeology

No groundwater was encountered during the construction of the trial pits or the windowless sample holes and no water strikes were recorded in the boreholes. Groundwater level monitoring is ongoing and will be updated as part of our addendum report.

4.3 Chronic Risks to Human Health – Generic Assessment of Risks

4.3.1 Assessment Methodology

The long term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

4.3.2 Assessment Criteria

In 2014, DEFRA published the Category 4 Screening Levels (C4SL) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. They are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). However, the C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). At the time of writing, the use of the C4SL in planning has not yet been accepted by many parties, including some regulators. The C4SL have also only been published for a limited number of contaminants. The C4SL have not been generally adopted in this assessment.

In this assessment, where available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) in the first instance. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments - not public open space). Where no SGV is available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) have been adopted (Nathanail et al, 2015). These assessment criteria adopt updated toxicological data and exposure models, but the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the

Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

At the time of writing there is no published SGV, S4UL or CL:AIRE/EIC assessment criteria for lead. For the purposes of this assessment, and in the absence of any other current authoritative guidance, the Category 4 Screening Level (C4SL) value published by DEFRA has been adopted. Details of the source of the GAC adopted for each contaminant are presented on the assessment table below. The proposed development will comprise a three storey school, single storey nursery, possible community café, MUGA pitch and associated external areas of hardstanding, parking and landscaping. We understand that no significant changes to the current ground levels are proposed.

There are currently no GAC published for such an end use. As discussed in Section 3.1.6, the critical receptors for a school are considered to be the staff (teachers and caretakers). Given this, we consider that the exposure scenarios adopted in the generation of the published GAC for a 'commercial' end use would be similar to those at the proposed development.

Therefore, for the purposes of this generic assessment, the GAC for commercial use have been adopted primarily. An assessment against the GAC for public open space around residential properties has also been undertaken to assess the risks to school children. However, as the exposure frequency/durations are different for this use, using these GAC is considered a conservative approach and an exceedance does not necessarily indicate an unacceptable risk.

4.3.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised 18no. samples of near surface soils. At this stage, all samples have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 7.1.1.

The results of the Generic Quantitative Risk Assessment are presented in Table 6 below.

Table 6: Summary of Geo-environmental Soil Results

Determinand	Range Recorded	GAC (Commercial)	GAC (Public Open Space)	Source of GAC	Exceedances
Metals and Semi-metals					
Arsenic	4.9 - 30mg/kg	640mg/kg	170mg/kg	SGV[2]	None of 18
Barium	14-750mg/kg	22,000mg/kg	22,000mg/kg	CL:AIRE[4]	None of 18
Beryllium	0.3 – 0.9mg/kg	12mg/kg	63mg/kg	S4UL[3]	None of 18
Boron	0.2-0.6mg/kg	240,000mg/kg	240,000mg/kg	S4UL[3]	None of 18
Cadmium	0.2-0.6mg/kg	230mg/kg	555mg/kg	SGV[2]	None of 18
Chromium (total)[6]	8.1-47.0mg/kg	8,600mg/kg	33,000mg/kg	S4UL[3]	None of 18
Chromium (hexavalent)	<1 mg/kg	33mg/kg	220mg/kg	S4UL[3]	None of 18
Copper	7.8 – 84.0mg/kg	68,000mg/kg	44,000mg/kg	S4UL[3]	None of 18
Lead	9.3-1700mg/kg	2,330mg/kg	1,300mg/kg	C4SL[5]	1 of 18
Mercury[7]	0.07-0.79mg/kg	3,600mg/kg	240mg/kg	SGV[2]	None of 18
Nickel	8.5-31mg/kg	1,800mg/kg	800mg/kg	SGV[2]	None of 18
Selenium	<0.6mg/kg	13,000mg/kg	1800mg/kg	SGV[2]	None of 18
Vanadium	9.6-34.0mg/kg	9,000mg/kg	9000mg/kg	S4UL[3]	None of 18
Zinc	34.0-320.00mg/kg	730,000mg/kg	170,000mg/kg	S4UL[3]	None of 18
Polyaromatic Hydrocarbons (PAH)					
Acenaphthene	0.04–0.15 mg/kg	84,000mg/kg*	29,000mg/kg	S4UL[3,8]	None of 18
Acenaphthylene	0.04-0.14mg/kg	83,000mg/kg*	29,000mg/kg		None of 18
Anthracene	0.04-0.44mg/kg	520,000mg/kg	150,000mg/kg		None of 18
Benzo(a)anthracene	<0.03 – 1.4mg/kg	170mg/kg	49mg/kg		None of 18
Benzo(a)pyrene	0.06-1.2mg/kg	35mg/kg	11mg/kg		None of 18
Benzo(b)fluoranthene	<0.03-1.8mg/kg	44mg/kg	13mg/kg		None of 18
Benzo(ghi)perylene	0.04-0.78mg/kg	3,900mg/kg	1,400mg/kg		None of 18
Benzo(k)fluoranthene	0.04-0.72mg/kg	1,200mg/kg	370mg/kg		None of 18
Chrysene	<0.03 – 1.5mg/kg	350mg/kg	93mg/kg		None of 18
Dibenzo(a,h)anthracene	<0.03– 0.22mg/kg	3.5mg/kg	1.1mg/kg		None of 18
Fluoranthene	0.05-2.9mg/kg	23,000mg/kg	6,300mg/kg		None of 18
Fluorene	0.04-0.28mg/kg	63,000mg/kg*	20,000mg/kg		None of 18
Indeno(123-cd)pyrene	0.04-0.68mg/kg	500mg/kg	150mg/kg		None of 18
Naphthalene	0.04 – 0.17mg/kg	190mg/kg*	1,200mg/kg*		None of 18
Phenanthrene	0.04 – 2.0mg/kg	22,000mg/kg	6,200mg/kg		None of 18
Pyrene	0.04-2.2mg/kg	54,000mg/kg	15,000mg/kg		None of 18

Notes

1. Assessment for commercial land use.
2. CLR SGV: Soil Guideline Value published by Environment Agency.
3. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
4. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
5. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
6. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
7. GAC for inorganic mercury adopted.
8. GAC for organic compounds based on 1% soil organic content.
9. ESP - Generic Assessment Criteria generated by ESP using CLEA software.
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix F.

The levels of lead were found to be elevated above the GAC for public open spaces in 1no. out of 18no. samples of Made Ground across the site. A further statistical analysis of the data considering individual averaging areas is considered warranted and follows in Section 4.3.5.

4.3.4 Asbestos

A qualitative analysis of all 18no. samples submitted to the laboratory has not identified the presence of any asbestos in the samples submitted.

4.3.5 Statistical Assessment

The results of the testing for determinands which have been identified at levels in excess of the Generic Assessment Criteria (GAC) have been assessed statistically in

accordance with CIEH/CL:AIRE (2008). The assessment has been undertaken for lead. The samples with elevated levels were only identified in Site A.

The levels of lead varied between 9.3 and 1700mg/kg, with a sample mean of 248.7mg/kg. An assessment of the data has identified one outlier (defined as a result than lies more than two standard deviations from the mean) being the maximum value from HDP3(0.4m). The statistical analysis also shows a non-normal distribution of results (see Section 6.0 for further discussion).

4.4 New Planting

Soil contamination can have a deleterious impact on the health of new plants. Such 'phytotoxic' effects can include inhibited growth, nutrient deficiencies and discolouration of vegetation. However, the potential impact on planting is difficult to quantify partly due to differing abilities of various plants to tolerate different soil conditions.

Contaminants are taken up by plants in a number of ways, the principal mechanism being via root uptake, but also including adsorption to roots. The impact on contaminants on plant growth depends on a number of factors, including the plant species, the soil type, the soil pH, the availability of the contaminant, and the impact of other external stresses on the plant such as drought.

The British Standard for the provision of Topsoil (BS3882:2007) provides guidance on acceptable levels of copper, nickel and zinc within a growing medium, which vary with soil pH value. ICRCL 70/90 (1990) discussing the restoration of metalliferous mining sites also provides 'threshold trigger levels' for a number of metals and fluoride, below which there should be no impact on plant growth. Finally MAFF (1998) provides assessment criteria for the assessment of the impact of a number of metals on the growth of plants. For the purposes of this assessment, we have adopted the BS3882 guidance values in the first instance, followed by the MAFF published guidelines, and finally the ICRCL 'trigger values'.

The assessment along with the assessment criteria adopted are presented in Table 7 below:

Table 7: Summary of Assessment Criteria for Planting

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	4.9 - 30mg/kg	250mg/kg	MAFF[1]	None
Cadmium	0.2-0.6mg/kg	3mg/kg	ICRCL[2]	None
Chromium (total)[6]	8.1-47.0mg/kg	400mg/kg	MAFF[1]	None
Copper	7.8 – 84.0mg/kg	200mg/kg (pH>7)	BS3882[3]	None
Lead	9.3-1700mg/kg	300mg/kg	MAFF[1]	2 of 18
Mercury	0.07-0.79mg/kg	1mg/kg	MAFF[1]	None
Nickel	8.5-31mg/kg	110mg/kg (pH>7)	BS3882[3]	None
Zinc	34 – 320 mg/kg	300mg/kg (pH>7)	BS3882[3]	None

Notes
1. MAFF: Ministry of Agriculture, Fisheries and Food guideline for maximum permissible concentrations in agricultural soils.
2. ICRCL: ICRCL 70/90.
3. BS3882:2007 – values dependent on soil pH values.
4. Laboratory test results presented in Appendix F.

The testing has indicated levels of lead to be present at concentrations which could be potentially phytotoxic to new planting. Of the exceedences recorded, all of the samples are noted to have been taken from Site A. This should be considered in designing the planting regime for the development.

4.5 Ground Gas

4.5.1 Degradation of Organic Materials

The likelihood and severity of a gassing event is considered as part of the risk assessment process in accordance with C665 (Wilson et al, 2007).

The Preliminary Risk Assessment (Section 3.1.3) has identified the following potential sources of hazardous ground gas within the site boundaries or in close proximity, which could impact on the proposed development:

- Alluvial soils – organic layers within the alluvium could generate combustible and noxious gases;
- General Made Ground – organic and other materials could generate combustible and noxious gases;
- Historic off site sources including infilled timber pond, canal, dockland etc.

Therefore, gas wells have been installed and monitored for hazardous gases on 4no. occasions to date (allowing for earlier installation of borehole wells) with an additional 3no. visits to be undertaken. The current monitoring has indicated no methane and levels of carbon dioxide up to 3.6%. A full assessment of gas risks will be presented in a gas addendum report on completion of monitoring, however, based on results to date and the historical/environmental setting for the site, ground gas protection measures are likely to be required.

4.5.2 Radon

As discussed in 2.9, no radon protection is required for the development.

4.6 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

4.6.1 Classification of Site:

Due to the presence of up to 5.7m of Made Ground comprising both general Made Ground and landfill material on the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

4.6.2 Groundwater Setting:

Groundwater was encountered in the exploratory holes and installed wells at a minimum depth of 0.6m in the shallow soils. Therefore, groundwater has been considered as mobile in this assessment.

4.6.3 Sulphate Levels:

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground soils in site A to be between 10 and 94mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.01 and 0.18% and total sulphur between 0.01 and 0.09%. From these results, the calculated levels of total potential sulphate are between 0.03 and 0.27%, and oxidisable sulphides are between -0.02 and 0.09%. As the level of oxidisable sulphides are less than 0.3%, pyrite is not likely to be present.

4.6.4 Foundation Concrete Design:

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site are (all as SO_4):

Water soluble sulphate:	94mg/l;
Total potential sulphate:	0.27%
pH value:	6.5

5 Phase Two Geo-Environmental Risk Assessment

5.1 Discussion on Occurrence of Contamination and Distribution

The site history has indicated that the site was previously occupied by extensive residential housing, roadways and external areas. The investigation thus far has identified a cover of Made Ground over further natural superficial deposits and Mercia Mudstone bedrock.

No obvious evidence for contamination or contaminating sources were identified during the investigation works.

Laboratory testing has indicated generally low levels of contaminants, however, an elevated level of Lead has been identified.

5.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Table 4, Section 3.2.2) have been updated and revised in Table 8 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 8: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils from general Made Ground and previous on site land uses (former buildings etc) and encroachment of off site uses (railways, infilled timber pond, canal, dock etc.).	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users	Medium – potential for chronic levels.	Likley[1]	Moderate Risk	Risk likely to be further reduced dependant on confirmed layout.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High likelihood[1]	Moderate/Low Risk	Likely to be managed with PPE however, sampling of near-surface soils to confirm levels of total contamination present.
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary Aquifer	Low likelihood	Moderate/Low Risk	Generally low risk anticipated based on available information.
Asbestos in shallow soils.	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low likelihood [2]	Moderate/Low Risk	No asbestos detected.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Low likelihood [3]	Low Risk	Generally low risk to concrete identified.
Hazardous ground gas/vapours from on and offsite sources including infilled timber pond, canal, docks etc. (see Section 3.1.4).	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors	Severe – acute risk.	High likelihood[4]	**High Risk**	Monitoring underway and to be updated on completion.
	Damage through explosion.	Building/Property	Severe – acute risk.		**High Risk**	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		**High Risk**	
Radon gas	Migration into Buildings	Site Users	Medium – potential for chronic levels	Unlikely[5]	Low Risk	No radon protection measures required.

Notes:

1. Although Made Ground is proven, contamination levels are generally low.
2. The presence of Asbestos Containing Materials or Asbestos within shallow soils has not been identified.
3. Generally low levels encountered.
4. Significant potential for on and off site ground gas sources and gas monitoring is ongoing.
5. Radon risk identified in environmental data report (see Appendix B).

6 Remedial Strategy For Contamination Risks

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

6.1 Preliminary Assessment of Risks to Health

6.1.1 Asbestos

No evidence of asbestos was detected at the site. However, it cannot be discounted that during the construction of the business park, excess building materials could have been placed on the site. Given the date of construction these should not have included significant amounts of asbestos, however, this cannot be totally discounted.

However, the site has been previously developed so the presence of asbestos in the shallow Made Ground and any so-far unidentified backfilled pits cannot be discounted. If any suspected asbestos containing materials (ACM) are identified during development, the advice of a suitably qualified specialist should be sought immediately. Any identified ACM would need to be removed from site by a licensed specialist contractor.

6.1.2 Site End Users

The site history has indicated that the site was previously occupied by extensive residential housing, roadways and external areas. The investigation thus far has identified a cover of Made Ground over further natural superficial deposits and Mercia Mudstone bedrock.

No obvious evidence for contamination or contaminating sources were identified during the investigation works. Laboratory testing has indicated generally low levels of contaminants, however, an elevated level of Lead has been identified. Statistical analysis has shown this sample (HDP3) to be an outlier and warrant further assessment.

If this portion of the site is not to be occupied by proposed buildings, further sampling and assessment will be required around HDP3 to further confirm the risk posed. If a zone of higher lead levels are identified and the area is to be used for outdoor space, the use of a suitable clean cover system may be required.

Whilst the concentrations of potential contaminants generally meet the guideline criteria, they will not be suitable for higher risk activities such as growing green/planting schemes and alternatives such as raised planters or clean imported soils will be required.

6.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

6.1.4 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks.

Notwithstanding the above, we recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

6.1.5 General Public/Neighbouring Properties

We do not anticipate any significant risks to the general public from the development of the site. However, careful dust control measures should be adopted during construction to minimise the risk (and nuisance) to the general public and neighbouring residents.

6.2 Risks to Controlled Waters

No specific assessment of the risks to controlled waters has been undertaken to date. However, the following points are considered salient.

- Made Ground has been identified on the site.
- No obvious visual or olfactory evidence of contamination.
- The site is located within an area of extensive historical development that includes commercial, industrial and dockland uses.
- The levels of soil contaminants are generally low..
- The proposed development comprises a schools development with external areas which are anticipated to be hard surfaced – surface drainage from these areas could contain leached oils and fuels from vehicle spills and leaks.
- The site is underlain by predominantly Made Ground overlying predominantly fine grained natural soils which grade into coarse deposits.
- The bedrock beneath the site is classified as a Secondary Aquifer and is not located with a Source Protection Zone.
- No shallow groundwater was encountered during the investigation.

We consider that the overall risk to controlled waters from the development of the site is likely to be low and no further assessment is warranted. .

6.3 Risks from Ground Gas

6.3.1 Risk to the Development – Degradation of Organic Material

Gas wells have been installed and monitored for hazardous gases on 4no. occasions to date (allowing for earlier installation of borehole wells) with an additional 3no. visits to be undertaken. The current monitoring has indicated no methane and levels of carbon dioxide up to 3.6%. A full assessment of gas risks will be presented in a gas addendum report on completion of monitoring, however, based on results to date and the historical/environmental setting for the site, ground gas protection measures are likely to be required.

6.3.2 Radon

As previously discussed, no radon protection measures are required for the development.

6.3.3 Risk to Construction and Maintenance Workers

The presence of elevated levels of methane, carbon dioxide and depleted oxygen in the Made Ground could pose a risk to construction workers, and lead to asphyxiation in confined spaces. All excavations should be treated as confined spaces and suitable precautions taken prior to man entry. This risk will be updated on completion of the ground gas monitoring.

6.4 Risks to Property

6.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low.

6.4.2 Sulphate Attack on Buried Concrete

The following characteristic values have been identified for concrete class:

Water soluble sulphate:	94mg/l;
Total potential sulphate:	0.27%
pH value:	6.5

Based on the characteristic values identified, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, allowing for mobile groundwater. .

6.5 Risks to New Planting

As discussed in Section 4.6, analysis of the shallow soils has indicated the levels of lead and zinc to be above the respective assessment criteria. Therefore, phytotoxic impact on future planting could occur. A landscaping specialist should be consulted with regards to any proposed future planting.

As part of this commission, a top soil resources survey has been undertaken and is provided in Appendix I. The recommendations and materials handling discussed in this report should be referred to as part of the detailed design and the recommendations contained within discussed and agreed with the local council.

6.6 Re-Use of Materials/Disposal of Excess Arisings

6.6.1 General Comments on Re-use/Disposal

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g. within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (Duckworth, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

1. Disposed at a licensed landfill;
2. Disposed at a licensed, permitted soil treatment centre; or
3. Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g. by requesting a copy of the Environmental Permit before releasing the soils). Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose– a WM3 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. Only once the soils have been classified under the WM3 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

6.6.2 Imported Materials

Any soils or materials to be imported to site (including Topsoil) should be certified clean and inert, and suitable for use. An appropriate number of samples (depending on the volume of soils imported) should be analysed for an appropriate suite of contaminants, and verification certificates should be provided. Further guidance can be provided by this office if required.

7 Geotechnical Comments

7.1 Site Preparation and Earthworks

7.1.1 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed or Himalayan Balsam was identified on the site during the site works. The potential for invasive species should be confirmed as part of detailed design.

7.1.2 Existing Foundations and Services

No evidence of old structures have been identified in the investigation, however, compacted earth basement floors where encountered across the site. In addition to the foundations of historic buildings there are likely to be obstructions and other historic features present at the site.

A number of services trend generally in a west to east direction in the north of the site. In addition to this, a large capacity brick “egg” sewer is present in the east portion of the site and trends north to south (see Figure 1).

A geophysical survey of the site has been carried out as part of the commission by Terradat and is presented in Appendix L. The report identifies a number of historic features and possible services and should be referred to as part of detailed design.

7.1.3 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

7.1.4 Earthworks

We have not been advised that the development requires any significant earthworks and understand that there are no significant changes to ground levels proposed. .

7.2 Sulphate Attack

As previously discussed, a concrete class of AC-1 will be required. Appropriate concrete design will be required.

7.3 Preliminary Foundation Design and Construction

The presence of compressible Made Ground and Tidal Flat Deposits possessing very low bearing and high consolidation properties could lead to significant and unacceptable settlements for developments constructed on shallow footings of any form. In addition to this a large capacity brick culvert trends through the site and is to remain. Therefore, we consider that for the proposed school building development, piled foundations would be required.

We consider that the piled foundations for the buildings should be taken down to the competent Mercia Mudstone Group bedrock strata encountered from depths of between 9.0m and 10.5m below ground level, however, the pile designer should undertake their own evaluation of site conditions for design and the following criteria should be considered for pile design:-

- The magnitude and resulting effect of different structural loadings.
- Possible impacts on neighbouring structures and underground services including the brick lined culvert on site;
- Pile/soil/structure interaction effects;
- The design philosophy for pile bearing capacity - the estimation of pile bearing capacity in the Mercia Mudstone requires careful consideration of the skin friction developed over the penetration depth into the rock and the end bearing resistance beneath the pile toe. Due to post-glacial chemical leaching of soluble minerals, the Mercia Mudstone is renowned for variable strength characteristics, including bands of low or zero strength.
- Buckling in the Tidal Flat Deposits/Made Ground;
- Negative skin friction forces from the Tidal Flat Deposits/Made Ground.

The final safe working load on the pile will be dependent on the pile type, diameter and length of the piles, the penetration into the bearing stratum, and the settlement tolerances required.

Based on the available information, and given the site constraints, it is likely that the most appropriate system is likely to be a driven, displacement pile system, which may prove most efficient for the particular ground conditions, particularly as the quantity of arisings will be limited. The use of driven piles should only be considered if vibrations and environmental constraints can be maintained within acceptable limits, with regard to the proximity of existing buildings and services.

Pile foundations will create a potential pollution pathway between the near-surface Made Ground, through a Secondary A aquifer (superficial deposits) and into the underlying Mercia Mudstone Bedrock which are classed as a Secondary B aquifer. Therefore, prior to piling it is essential that a piling risk assessment is undertaken to determine risks posed to the aquifer.

Discussions should be held with specialist piling contractors to obtain specific piling proposals based on their particular proprietary system and to evaluate costs. The piling contractor should be asked to provide a pile design and method statement to include performance specification and in particular the magnitude of total and differential settlements which could be guaranteed and how the design will accommodate strength and depth variations across the site. Test loading will be required on a proportion of the piles to confirm that they are adequate to carry the design working loads, and the contractor should monitor closely the pile installations to satisfy himself that the ground conditions encountered are as good as, or better than, those assumed in his design. Care should be taken to ensure that piles are not stopped short on obstructions.

If required, further guidance on design criteria can be given by this office when structural loadings, design and cost implications have been finalised.

7.4 Floor Slab Foundations

Due to the presence of a significant cover of Made Ground and soft compressible Tidal Flat Deposits at the site, we consider that ground bearing floor slabs would not be suitable for the development, and floor slabs should be suspended. Floor slabs will also need to be designed to accommodate ground gas protection measures, which are anticipated.

7.5 Pavement Design

We understand that vehicle access roads/hardstanding are proposed at the site. Based on the encountered ground conditions, a CBR values of <2% would be appropriate for the near surface Made Ground, with an improvement in values likely with depth. California Bearing Ratio (CBR) tests, via TRL probe, are to be carried out at the site during one of the monitoring visits and this aspect of the assessment will be updated when completed.

7.6 Susceptibility to Frost Action

The near surface fine grained Made Ground is considered to be frost susceptible. Where the soils are identified as frost susceptible a total thickness of 450mm non-frost susceptible pavement construction will be required to avoid frost heave.

7.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. Old foundations will require higher capacity machines for their removal.

For shallow excavations where there is no danger to life, support of excavation sides is unlikely to be necessary, however, should any indication of excavation instability be noted above this depth, support should be provided as appropriate.

Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

7.8 Soakaway Testing

ESP have undertaken a limited previous phase of works at the site in order to determine the likely infiltration characteristics of the near surface soils. Five infiltration tests were undertaken in December 2018 and it was recorded that over the 24 hours, none of the tests recorded a drop in head of water that allowed an infiltration value to be calculated. As such, it was reported that based on the available information, soakaway drainage was unlikely to be suitable for the development.

8 Recommendations

Based on the available information no further information is required to progress the scheme at present, however, the following additional/completing works will be required to progress the detailed site design..

Ongoing Requirements

- Completion of ground gas monitoring and subsequent ground gas addendum report;
- Undertaking of CBR tests across the site during monitoring visits.

Subsequent Requirement

- Confirmation of layout location and design and review of this report;
- Provision of a detailed UXO report and/or supervision requirements;
- Confirmation of anticipated low risk from invasive species;
- Supplementary assessment in the area of HDP3 and further analysis of the risk posed by lead if the area is not to be covered by a building;
- Watching brief for anomalous ground conditions associated with historical development;
- Careful identification of services and reference to geophysical survey;
- Pile design specification and piling risk assessment if required.

ESP are able to assist in the implementation of any items not already being addressed when required.

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