Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Land at Chartist Way, Tredegar

Proposed Primary School

Exploratory Investigation

Report Reference: ESP.7777b.3543

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Land at Chartist Way, Tredegar
Proposed Primary School
Exploratory Investigation

Prepared for:
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Blaenau Gwent
County Borough Council

Report Reference: **ESP.7777b.3543**

Revision	Status	Date	Written by	Checked by	Approved by
0	Draft	Hywel Davies	Hywel Davies	Hywel Davies Giles Sommerwill	Giles Sommerwill
		Signature:	MESci FGS CGeol RoGEP Professional	MESci FGS CGeol RoGEP Professional BSc (Hons) MSc CGeol SiLC FGS RoGEP Specialist	BSc (Hons) MSc CGeol SiLC FGS RoGEP Specialist
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Plates

Executive Summary

Blaenau Gwent County Borough Council is considering the redevelopment of the site as a primary school. ESP have undertaken a geo-environmental and geotechnical assessment and the key potential land quality issues identified by the assessment are summarised below:

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	*Current Site Status. (Section 2.1)*	-	*It is occupied by a series of grassed fields used as grazing land and a playground. A 20 to 25m high wooded slope is on the west boundary.*
	Identified Ground Conditions. (Section 5.1)	-	*Thick Made Ground consisting of colliery spoil to a max depth of 14m, followed by fine grained possible glacial soils/weathered Lower/Middle Coal Measures bedrock (L/MCM). Competent interbedded mudstones, sandstones and coal seams were encountered below with evidence of mine workings at <30m depth.*
	Groundwater Conditions. (Section 5.2)	-	*The glacial superficial deposits are classified as a Secondary Undifferentiated Aquifer and the L/MCM as a Secondary A Aquifer. Localised perched water was identified in the Made Ground.*
	Historical Land Use. (Section 2.2)	-	*The site was heavily industrialised, with building and infrastructure associated with the Sirhowy Ironworks. By the 1920s, the majority of these industrial features were no longer apparent. In the early 1980s, a level plateau was created which later became a series of fields and playground.*
Geo-environmental	*Potential Contamination Sources (Section 3.1.2)*	Moderate to High	*The former industrial uses are potentially contaminative. Whilst the fill materials used to level the site were likely sourced from these historic activities, other contaminated materials may have been deposited. A sewage pollution event may have occurred on the site (to be confirmed).*
	Chronic Risks to Human Health (Section 7.1)	Low	*The levels of soil contamination are not considered to pose a risk to future site users. No specific remedial measures are considered necessary. Confirmation of the low risk is required in un-investigated areas. If any evidence contaminated soils is identified, further geo-environmental specialist advice should be sought.*
	Risks to Controlled Waters (Section 7.2)	Low	*Considering the historic industrialisation of the area it is unlikely that the slightly elevated leachate/groundwater levels would be regionally significant. We consider the risk is low and remediation is not warranted.*
	Hazardous Ground Gas (Section 7.3)	High	*Elevated levels of ground gases have been encountered to date. Additional monitoring is to be undertaken and the risks will be assessed in a ground gas addendum. No radon protection is required. Further gas monitoring will likely be required post completion of the remedial grouting works.*
Geotechnical	*Abandoned Mine Workings and/or Old Mine Entries (Section 8.2.2)*	High	*A high subsidence risk is posed from extensive shallow underground coal and ironstone mine workings and mine entries and further assessment and remedial action is required.*
	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.3 and Section 8.4)	Moderate to High	*We recommend a reinforced raft foundation constructed on compacted fill. The presumed bearing value of the re-compacted fill would be dependent on the foundation size, the material type and quality, the compaction characteristics and foundation loading details.*
	Shrinkage or Swelling (Section 8.2.3)	Low	*The compacted fill will be coarse grained and therefore will not be susceptible to shrinkage and swelling.*
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Low	*We consider the site would be classified as DS-1 and AC-2z, allowing for mobile groundwater.*
	Soakaway Feasibility (Section 8.8)	-	*Soakaway drainage may be feasible in the Made Ground, however testing will be required in the specific location. They should be positioned away from the proposed buildings and existing slopes. Regulatory approval will need to be sought considering potential controlled water risks.*
	Slope Stability	-	*Once the layout and design has been finalised potential effects on the stability of the slope on the west boundary should be checked. Changes in surface water or groundwater (e.g. soakaway infiltration) flow may influence the stability of the slope and will require consideration.*
Others	*UXO (Section 2.10.8)*	-	*A specialist assessment concludes that 'a detailed desk study, whilst always prudent, is not considered essential in this instance'.*
	Flooding (Section 2.6)	Low	*A low flood risk from rivers and surface water has been identified.*
	Invasive Plants (Section 8.1.2)	-	*No invasive plants was identified during the works. However, their growth is seasonal and therefore their presence cannot be discounted.*
	Further Investigation Required?	Yes	*See Section 9.*

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

Blaenau Gwent County Borough Council (hereafter known as the Client) are proposing to redevelop the subject site as a primary school. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an integrated 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 on Insert 2 in Section 2.1.

The proposed development will comprise a single storey school building with associated play areas, access road, bus turning circle, car parking and landscaped areas. We understand that in order to construct a suitable development plateau, ground levels in the east will be lowered, and the excavated soils used as fill to raise ground levels in the west, however specific levels are not currently available. The proposed development layout is presented as Insert 1.

Insert 1 - Proposed Development Plan (Client Ref: TS1297 Sk04/S1)

Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2015+A1:2020).

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.

The scope of works for the investigation was primarily designed by the Client with additional input by ESP based on emerging conditions within an agreed budget, and comprised a desk study review of available historical Ordnance Survey maps, environmental data, geological maps, memoirs and data, and further desk study information, a field reconnaissance visit, the supervision and direction of cable percussion boreholes, trial pits, rotary drillholes, soakaway infiltration testing, measurement of in-situ CBR values (using DCP equipment), geotechnical and geo-environmental laboratory testing, gas and groundwater monitoring, assessment 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 5th February 2021 (ref: db/7777b.lt1).

The investigation and assessment was undertaken between March and June 2021.

1.3 Report Format

This report includes the desk study and field reconnaissance reports (Section 2), and details of the investigation undertaken of Eurocode EC7 and BS5930:2015 (Section 4), along with the Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of the land contamination risk management (LCRM) guidelines (formerly CLR11). 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 in Sections 6 and 7. However, it should be appreciated that this is a preliminary evaluation only, and will not generally meet the requirements of the LCRM guidelines.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, 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 8 – this complies the relevant elements of the Geotechnical Design Report of BS EN 1997-2 (Eurocode 7) and BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

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.

This report is issued as a digital version only.

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 above. 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.

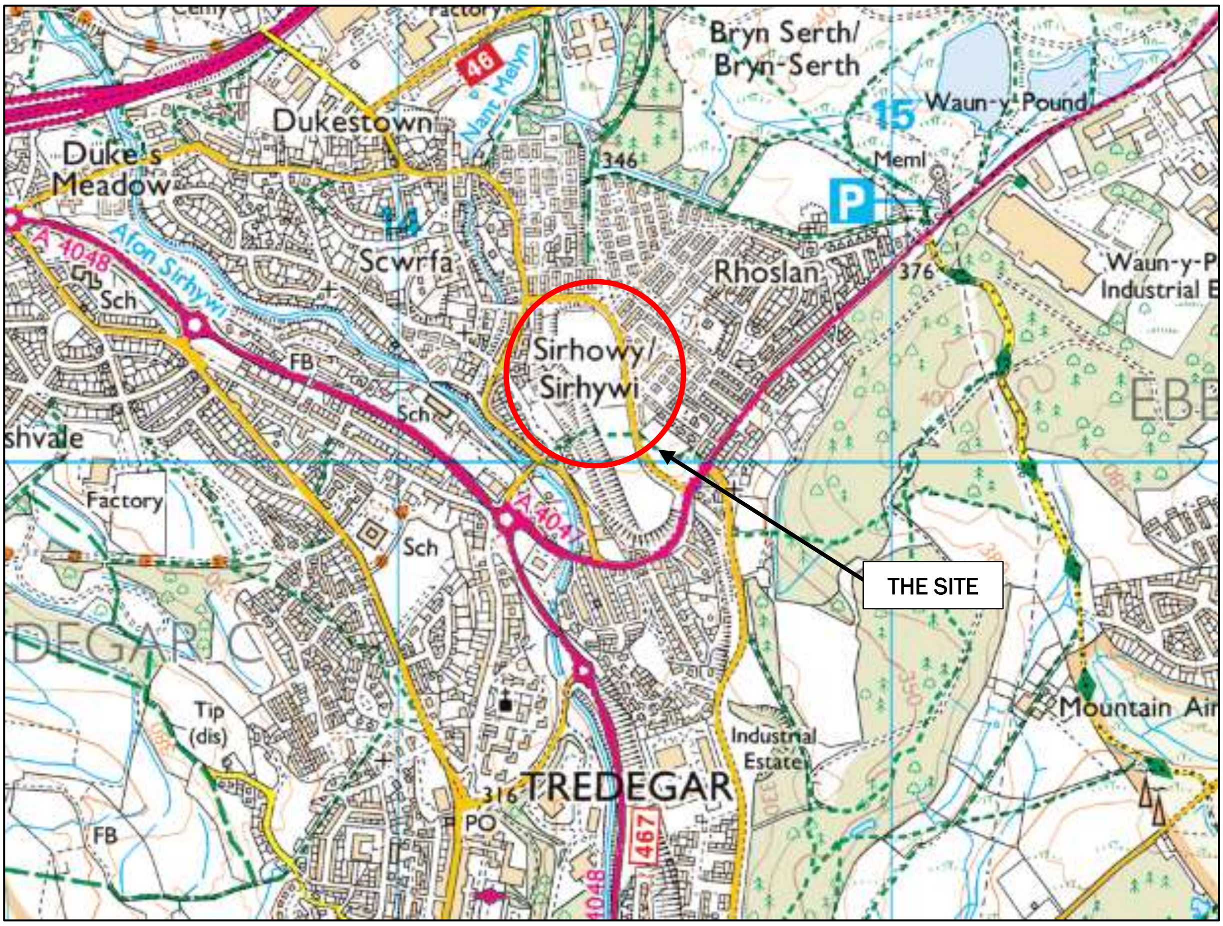
2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps, an environmental data report, a geological data report, information on a previous investigation at the site, and a mining report obtained from the Coal Authority. Further desk study reports/data/records are included as subsequent appendices as referenced in the text.

The site description is largely based on a field reconnaissance and site inspection visit made at the time of the site works (March 2021) during dry weather, and general views of the site are included as a series of photographs within the Plates section of this report.

2.1 Site Location and Description

The site is located on the south and west side of Chartist Way in the Sirhowy area of Tredegar. The National Grid Reference of the centre of the site is (SO) 314380E, 210215N and the postcode is NP22 4PR. A Site Location Plan is presented as Insert 2 below.



Insert 2 - Site Location Plan from Ordnance Survey 1:25,000 scale map.
Reproduced with permission (OS License No.: AL100015788).

The site comprises an irregular shaped parcel of land of around 220m length (north to south) and between around 80m and 115m width (east to west), occupying an area of around 2.3ha. It is presently occupied by a series of grassed fields used as grazing land and a playground in the north east portion.

It is bounded by:

- To the north: Chartist Way and residential housing.
- To the east: Chartist Way and residential housing.
- To the south: further grassed fields.
- To the west: by a wooded slope which lead down to the historic iron works, residential housing and the Sirhowy River beyond.

Vehicular access to the site is currently gained via a gate on the east boundary. The boundaries generally comprise post and wire fences.

The slope on the west boundary is wooded, however there are no mature trees on the site itself. We are not aware of a tree survey having been undertaken at this stage. A tree survey may be considered prudent if the trees on the western boundary are likely to influence the proposed development.

The general topography in the area slopes down towards the Sirhowy River around 200m to the south west. A topographic survey provided by the Client indicates the site also slopes in this direction from around 348 to 349m AOD at the east boundary on Chartist Way to around 342 to 343m AOD at the west boundary. The slope on the west boundary falls around 20m to 25m to the west.

The Client has provided ESP with a series of plans showing the locations of recorded underground services in the vicinity. Observations and the utility plans indicate the following services:

- A gravity surface water drain slightly encroaches and extends along the boundary in the north west portion.
- Underground BT services are present in the north east portion and along the boundary with Chartist Way.
- No electric or gas services are indicated, however they are present in Chartist Way.

2.2 Site History

2.2.1 Published Historical Maps

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. Extracts from the historical maps are presented in Appendix B and the salient features since the First Edition of the County Series maps are summarised in the table below.

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1879	The site is part of Sirhowy Iron Works and spoil material and earthworks are present throughout. A coke oven slightly encroachs in the south west and a smithy is present in the central portion. Railway lines extend throughout in a general north to south direction. A circular feature and a probable small pond are present in the centre and a pond encroaches in the south east. Terraced housing is present in the north west.	The surround area is heavily industrialised. Additional features associated with the iron works are present adjacent to the west and south boundaries including coke ovens, blast furnaces, railway land and engine houses. A large tip extends from within the site to the west. A brick works is present around 85m to the south east. Numerous mining features are present in the general area including shafts around ??? to the south east and an air shaft around 110m to the north and shaft around 120m to the south east. Large water bodies are present around 80m to the south east and 140m to the north east.

Table 1 (continued): Review of Historical Maps

Date	On-Site	In Vicinity of Site
1899 - 1901	The circular feature is named a feeder. Some of the railway lines have been dismantled.	Many buildings associated with the iron works are no longer present to the east. Whilst not indicated previously, old coal levels are noted around 50m to 100m to the west and south in areas formerly occupied by ironworks structures. The shafts to the south east are named the Fan Coal Pit. The large water bodies are labelled Feeders.
1920 – 1938	The smithy, feeder and coke oven are no longer present and further railway lines have been dismantled. A railway line extending north to south through the site is labelled a Mineral Railway. An old coal level is indicated on the west boundary.	The iron works infrastructure is no longer apparent and some residential development has occurred in areas to the west and generally. Walter's coal level is indicated around 20m to the south. The water body to the south east has been infilled and a brick works is indicated around 85m to the south east. Some of the former old levels are no longer indicated.
1949 - 1961	Only the mineral railway now remains. Earthworks have occurred and by the 1960s some development in the form of small buildings and associated land is present in the west. A track is noted in the west.	Residential development has continued in the vicinity. The mining features are no longer identified. Earthworks associated with former industry remains in the vicinity. A garage is indicated around 50m to the west. The brickworks has expanded and is now identified as a works.
1971	The mineral line is no longer present. Additional tracks are present. A small circular features is present in the south east (possible shaft).	A spoil heap is indicated around 50m to the east. The brick works is disused. Further residential development has occurred.
1982 - 1987	The site is now vacant and forms part of an undeveloped parcel of land which later becomes fields. No earthworks are now indicated as it has become a levelled plateau. A playground is indicated in the north west.	An earthworks embankment slope is indicated on the west boundary. An old coal level is located at the foot of the slope. Chartist Way forms the east boundary and residential development is present beyond. The brickworks and feeders are no longer present.
1993 – Present	No significant changes indicated.	No significant changes indicated.

Notes:
1. Extracts from historical maps presented in Appendix B.
2. Features may have been present on site between the dates of the individual mapping, and it should be appreciated that these cannot be identified from the map review.

In the late 1800s the site was heavily industrialised, with building and infrastructure associated with the Sirhowy Ironworks. By the 1920s, the majority of these industrial features were no longer apparent, however earthworks and spoil associated with the former activities and one railway line remained until the 1970s. In the early 1980s, a level plateau was created with an embankment on the west boundary and Chartist Way on the east. By the late 1980s, the plateau became a series of fields with a playground as per the current status. No further changes have occurred.

Extensive mining has occurred in the close vicinity (levels, shafts and pits) and an old coal level and possibly other features were formerly present on-site.

2.2.2 Other Sources

No further relevant information on the site history has been identified as part of this assessment.

2.3 Previous Investigations and Assessments

We are not aware of any previous geotechnical or geo-environmental investigations or assessments at the site.

2.4 Contact with Regulatory Bodies & Local Information Sources

The Local Authority (Blaenau Gwent County Borough Council) has been contacted as part of this assessment.

At the time of issue of this report, we have not yet received a response from the consultees. Once received, any response will be forwarded under separate cover. It should be appreciated that their responses may contain salient information on the site which could not be taken into account during the preparation of this report.

2.5 Hydrology

2.5.1 Surface Water Features

The nearest major surface water feature to the site is the Afon Sirhowy which flows from north west to south east approximately 140m to the south west. A number of streams/brooks are also present in the area, the closest of which is Nant Melyn (a tributary of the Sirhowy) some 110m to the west (see Appendix C).

The nearest surface water features are at a lower elevation than the study site.

2.5.2 Surface Water Abstractions

The data report (Appendix C) indicates that there are no surface water abstractions within 250m. The closest is 941m to the north east.

2.6 Flooding

2.6.1 Rivers and Seas

From a review of topographical plans and flooding maps presented in the environmental data report and on the Natural Resources Wales (NRW)/Environment Agency (EA) website (EA, 2019), the site is located in Flood Zone 1 and not indicated to be at risk flooding from rivers (fluvial) or seas (tidal). Flood Zone 1 is defined as an area during any given year that has less than 0.1% (1 in 1000) of flooding from rivers (fluvial) or seas (tidal).

The potential for flooding from rivers or seas has not been addressed further in this report.

2.6.2 Surface Water

Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. This type of flooding can be difficult to predict, much more so than river or sea flooding as it is hard to forecast exactly where or how much rain will fall in any storm. The information available depends on available records including ground levels and drainage.

The data report in Appendix C indicates the site to be outside areas at risk of surface water flooding and is described as Negligible Risk, defined as an area that in any given year has less than 0.1% (1 in 1000) chance of surface water flooding.

2.6.3 Groundwater

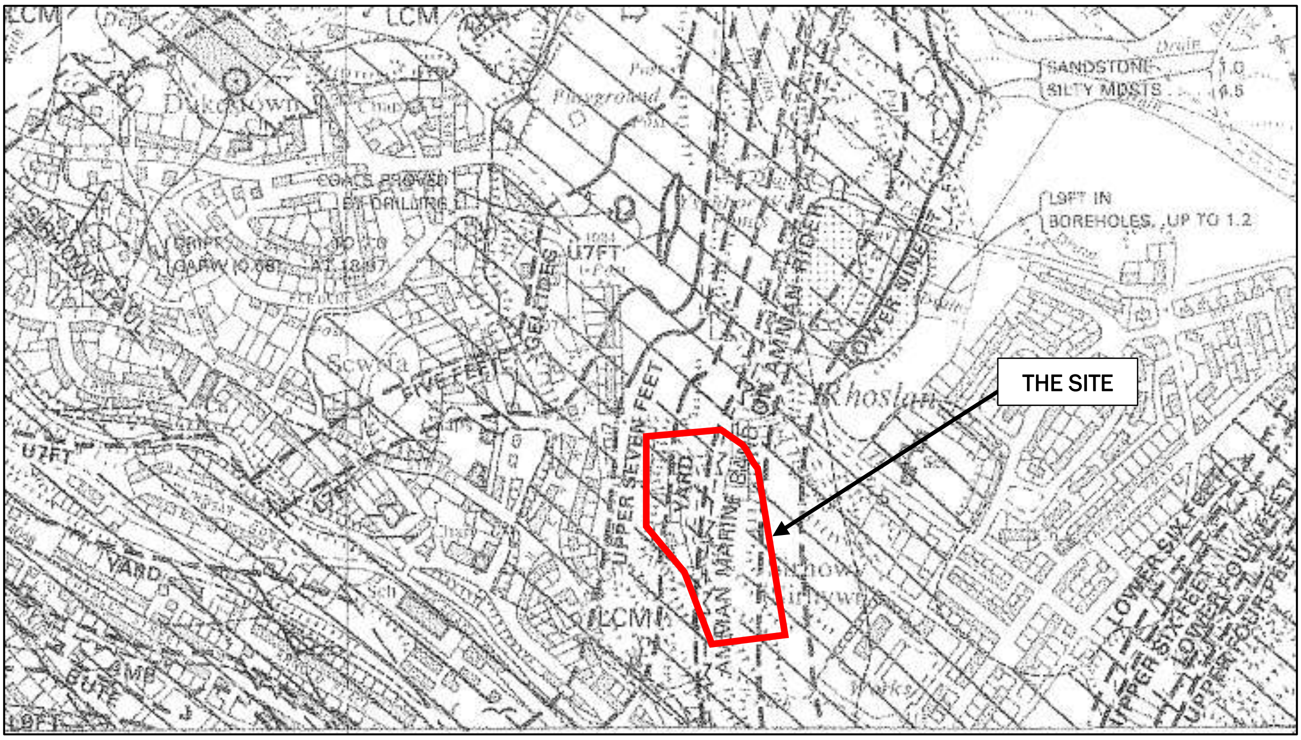
Groundwater flooding is defined as the emergence of groundwater at the ground surface away from river valleys or the rising of groundwater into man-made ground under conditions where the 'normal' range of groundwater levels and groundwater flows is exceeded and predicted risk from groundwater flooding aims to identify locations where this form of groundwater flooding could happen. It does not incorporate anomalous discharge from springs leading to groundwater flooding down the topographic slope or flooding associated with urban groundwater rebound, mine water discharge, urban drainage, or any other flooding associated with changes in the engineered environment.

The data report in Appendix C indicates that the site is at a low risk from groundwater flooding.

2.7 Geology

2.7.1 Published Geology

The published 1:10,560 scale geological map for the area of the site (Sheet SO11SW, presented as Insert 3) indicates the site to be underlain by Made Ground overlying bedrock of the Lower and Middle Coal Measures (LCM and MCM). Glacial Diamicton is indicated in the general area and is also likely present above the bedrock. Reference to the up-to-date mapping available on the website of the British Geological Survey (BGS, 2021) indicates a similar succession, but the Glacial Till has been renamed Diamicton.



Insert 3 - Extract from BGS Geological Map Sheet SO11SW, original 1:10,560 scale. Reproduced with permission (BGS licence number: C15/05 CSL)

The Glacial Till superficial strata would be expected to be fine-grained in nature with some gravel, and possibly cobbles and boulders. The Coal Measures bedrock comprises an interbedded succession of sandstone, siltstone and mudstone, with coal seams and associated seat earths.

From west to east, the geological map indicates the conjectural outcrops of the Yard, Amman Rider (AR) and Bute Coal seams to extend north to south within the site. The Amman Marine Band is also present. The stratigraphic section which also indicates the seam thicknesses is presented as Insert 4.

Insert 4 - Stratigraphic Section from SO11SW

The strata is indicated to dip 4 to 5 degrees to the south east. Therefore, the Upper Seven Feet (U7FT), Lower Seven Feet (L7FT) and Five Feet- Gellideg (5FT- Ge) seams, which are indicated to outcrop to the west, would also be expected to underlie the site. The Lower Nine Feet (L9FT) is conjectured to outcrop to the east, however considering the uncertainty over it's position, it cannot be discounted that this may also underlie the site.

Whilst not indicated in the stratigraphic section for the map, ironstones are known to be present throughout the LCM.

2.7.2 Available BGS Borehole Records

Reference to the website of the British Geological Survey (BGS, 2021) indicates the available records of two boreholes within 100m of the site. Copies of the available borehole records are presented in Appendix D and a plan showing their positions relative to the site as Insert 5.

Insert 5 - Plan of BGS boreholes near the site (from online BGS viewer)

SO11SW85 is named 'Navigation/Brickyard level' and is located around 50m to the south west. The record provides a section through the coal seams and ironstones that would likely underlie the site at shallow depth based on the regional dip. In summary:

- Yard Coal Seam (aka Engine coal) ~ 1.6m thick with partings;
- U7FT (aka Gwar-y-Cae/Meadow Vein) ~0.7m thick;
- L7FT (aka Yard Vein) ~ 1.5m thick with parting;
- 5FT- Ge coal (aka Old Coal) ~2.3m thick (with partings).
- Ironstones are noted throughout the section including the 'Little Pins' between the U7FT and L7FT.

The record is supported with discussion with regards to whether the level is in the Yard or the U7FT coal seam. We have not considered this further at this stage. The record confirms that the U7FT was extracted from the level at two different periods.

SO11SW56 is located around 85m to the east and was constructed in 1973. Whilst the borehole is located up dip, it progresses deep enough to intersect coal seams and ironstones that would underlie the site. In summary:

- L9FT coal seam (indicated to outcrop to the east and may not be beneath the site) – Mine workings encountered as cavities and backfill. Possible subsidence collapse is suggested (~4.8m thick);
- Bute coal seam (aka Darren Pins coal) – Old workings identified (~0.6m thick);
- Yard Coal Seam (aka Engine coal) – appears to have been worked (~0.8m thick);
- U7FT (aka Gwar-y-Cae/Meadow Vein) – intact coal seam (~1.0m thick with parting);
- Some evidence of ironstone nodules within the strata. The stratigraphic section indicates the ironstone between the Bute and Amman Marine band is called the Lower Darren Pins.

2.8 Hydrogeology

2.8.1 Aquifer Classification

Reference to the aquifer maps published in the data report (Appendix C) indicates that the superficial deposits beneath the site (Glacial Diamicton) are classed as Secondary Undifferentiated Aquifer, whilst the bedrock (Coal Measures) is classed as a Secondary A Aquifer.

Secondary A Aquifers generally correspond with the previously classified minor aquifers, and comprise permeable layers capable of supporting water at a local, rather than strategic, scale and in some cases form an important base flow to rivers. Secondary A Aquifers are sensitive to pollution.

Secondary Undifferentiated Aquifers are assigned by the Environment Agency where it has not been possible to categorise an aquifer in either Secondary A or B. In most cases this is attributable to a unit being classified as both minor and non-aquifers in different locations due to the variable characteristics of the rock type. These strata can be sensitive to pollution.

2.8.2 Anticipated Groundwater Bodies

Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the Coal Measures strata.

Localised perched water bodies within the overlying Made Ground and glacial soils cannot be discounted, particularly where there is a permeability contrast between two strata.

2.8.3 Abstractions and Groundwater Vulnerability

The data report (Appendix C) indicates that there are no groundwater abstractions or Source Protection Zones within 1km of the site.

The groundwater vulnerability in the superficial and bedrock aquifer is shown to be 'secondary aquifer low'.

2.8.4 Groundwater Movement

Groundwater movement within the glacial superficial deposits will be controlled by intergranular flow whilst, in the Coal Measures bedrock, fracture flow is likely to be dominant. Perched water flow in the Made Ground will likely be controlled by intergranular flow.

Given the site setting, we consider that groundwater flow will be towards the west towards the River Sirhowy and may be providing base flow.

It should be appreciated that in former mining areas, such as this, groundwater conditions may still be changing in response to the cessation or reduction in pumping from underground coal workings (see Section 2.10.1).

2.9 Environmental Setting

2.9.1 Summary of Environmental Data

The site exists in a historically industrial and now a suburban and industrial setting.

A data report has been obtained for the site and is presented in Appendix C, and the relevant data therein is summarised in the table below. The report should be consulted for further detail.

Table 2 - Summary of Environmental Data

Feature	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites[2,3]	None identified.	None recorded within 250m of the site.
Potentially Contaminative Land Use	Extensive industrialisation including railway land, ironworks, smithy, mining and subsequent earthworks (see Section 2.2 for details)	Surrounding area heavily industrialised and numerous contaminative uses identified including ironworks, brickworks, railway land, mining and earthworks.
Historical Tanks, PFS, Garages, Energy Facilities	An unspecified tank is indicated on-site. This is likely the 'feeder' indicated on the historical mapping and likely contained water.	Nothing indicated within 40m. Beyond this tanks, garages and electric sub-stations are noted.
Potentially Infilled Land	Not identified in the report. Extensive earthworks have occurred, including filling to create a level platform.	Extensive earthworks in the surround in area associated with mining, industrialisation and subsequent reclamation. Large water bodies (former feeders) infilled in the surrounding area (closest around 80m to the south east).
IPPC Authorisations	None identified.	None recorded within 500m of the site.
Discharge Consents	None identified.	None recorded within 150m of the site.
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 500m of the site.
Radioactive Substance Sites	None identified.	None recorded within 500m of the site.
Enforcements	None identified.	None recorded within 500m of the site.
Pollution Incidents	Storm sewage materials in 2001 – Minor impact to Water and Air (Cat 3). No impact to land (Cat 4).	None recorded within 100m of the site.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 500m of the site.
Landills/Waste Management Facilities	None identified. Extensive filling has occurred on-site.	None recorded within 300m of the site.
Current Industrial/ Commercial Sites	None identified.	None recorded within 50m of the site.

Notes:
1. Full details of features presented in data report (Appendix C).
2. Sensitive land uses include Sites of Special Scientific Interest, Nature Reserves, National Parks, Special Areas of Conservation, Special Protection Areas, Ramsar sites, World Heritage sites and Ancient Woodland.
3. Nitrate vulnerable areas relate to the agricultural use of fertilizers and are not considered further in this assessment.

2.9.2 On-Site Bulk Liquid Storage

The historical maps and field reconnaissance visit have provided no evidence of any past or recent above ground or underground bulk liquid (e.g. fuels/oils) storage on site.

2.9.3 On-Site Bulk Materials and Waste Storage

The field reconnaissance visit indicated no evidence of recent materials or waste storage on the site.

2.10 Preliminary Geotechnical Risk Register

The potential for various geotechnical and geomorphological hazards at the site is provided in the data report (Appendix C). The potential hazards, as defined by the British Geological Survey (BGS) and reported in the above report, along with any salient further information has been considered in the preparation of this report.

Where a potential geotechnical hazard has been identified, it is discussed further in subsequent sections.

2.10.1 Past Mining

As discussed in Section 2.7, the site is underlain by bedrock of the Lower and Middle Coal Measures, which contains several seams of coal (and bands of ironstone).

2.10.1.1 Historical and Geological Information

Historical information indicates extensive coal and ironstone mining in the general area. An old coal level is indicated on-site in the east portion.

From west to east, the geological map indicates the conjectural outcrops of the Yard, Amman Rider (AR) and Bute Coal seams to extend north to south within the site. The Amman Marine Band is also present. The Upper Seven Feet (U7FT), Lower Seven Feet (L7FT) and Five Feet- Gellideg (5FT- Ge) seams are indicated to outcrop to the west and would also be expected to underlie the site at shallow depth. The Lower Nine Feet (L9FT) is conjectured to outcrop to the east, however considering the uncertainty over it's position, it cannot be discounted that this may also underlie the site. BGS borehole information within 100m records workings in the L9FT, Bute, Yard and UP7FT coal seams.

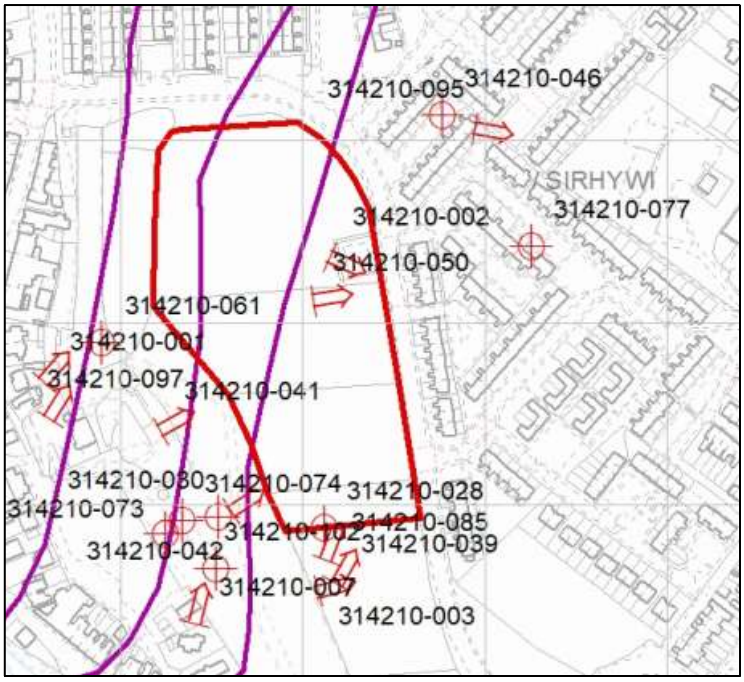
Whilst not indicated in the published stratigraphic section for the map, ironstones are known to be present throughout this part of the succession and the BGS boreholes identify the 'Little Pins' between the U7FT and L7FT and the Lower Darren Pins between the Bute and Amman Marine band. Online information also suggest that an Upper Darren ironstone exists in the area.

2.10.1.2 Coal Authority Website

Reference to the Coal Authority website (CA, 2021) provides the following salient information:

- The outcrop of possibly three unnamed coal seams are shown to cross the site in an east-west direction, however the resolution is poor. Reference to the published geology (Section 2.7.1) suggests that these are the Yard, Amman Rider and the Bute coal seams.
- No past surface hazard or surface mining is identified in the vicinity.
- Past shallow coal mining is indicated beneath and in the vicinity of the site.
- Mine entries are shown within the site boundary. However, the number is difficult to ascertain due to the resolution of the viewer. Further information in this regard is provided in the following section.
- The entire site lies within a 'Development High Risk Area'.

2.10.1.3 Coal Authority Mining Report



Insert 6 - Excerpt of Coal Authority Summary Map (taken from Consultants Report)

A consultants mining report has also been obtained from the Coal Authority and is presented in Appendix F. This indicates that, based on the available Coal Authority records:

- There are recorded workings in 3no. ironstones and 4no. coal seams at depths of less than 40m beneath the site.
- The shallowest workings are indicated to be in the Upper Darren Ironstone at a depth of 9m with an extraction thickness of 2m.
- There are 5no. spine roadways beneath the site, with a further roadway within 10m. No depths are indicated or what seams these roadways are within.
- There are no unrecorded mine workings beneath the site.
- The Bute and an unnamed coal seam (possible Amman Rider) are indicated to outcrop on-site with the L7FT indicated to outcrop around 20m to the west. The outcrop locations are indicated as proven. All seams are indicated to be workable. The outcrop naming does not correlate with the published geology.
- There are 19no. mine recorded entries within 100m of the site and all are indicated to be associated with coal – see below for further discussion.
- 2no. adits are located in the east portion and no records of treatment are available (CA Refs: 314210-002 and 314210-050). These entries correspond with the level identified on the historical mapping data and may be a duplication of the same entry.
- An adit (CA Ref: 314210-85) and shaft (CA Ref: 314210-028) is located on the south boundary and an adit (CA Ref: 314210-074) on the south west boundary. No records of treatment are available.
- There are no recorded geological faults or fissures recorded beneath the site.
- There are no recorded damage notices or claims for the subject property, or any property within 50m of the site boundary, since 31st October 1994.
- There is no record of any request having been made to carry out preventive works before coal is worked under section 33 of the Coal Mining Subsidence Act 1991.
- No mine gas emission has been recorded within 500m of the property.

- There is no proposed future mining or licensing proposed.
- No notices have been given under Section 46 of the Coal Mining Subsidence Act 1991 stating that the land is at risk of subsidence.

A Coal Authority stability report (dated March 2019) provided by the Client as part of the commission provides no further information to that described above.

2.10.1.4 Preliminary Coal Mining Risk Assessment

The Coal Authority indicate extensive coal and ironstone workings beneath the site at shallow depth (less than 30m) and untreated mine entries are recorded on-site and in adjacent areas. The presence of spine roadways indicate the workings could be significant in localised areas, however the depth of these unknown. Abandonment plans should be obtained to attempt to confirm whether these are within shallow coal seams beneath the site.

Further unrecorded underground coal and ironstone mine workings and mine entries cannot be discounted, considering the economic viability and accessibility of the coal and ironstone strata beneath the site.

A very high subsidence risk is posed to the proposed development and investigation is required to determine the depth and condition of coal and ironstone strata beneath the site. Remedial works in the form of drilling and grouting is likely and the design will also need to incorporate measures to limit effects of future potential ground movement (e.g. reinforcement).

It should be appreciated that all coal reserves, including abandoned workings are under the ownership of the Coal Authority (or the Forestry Commission in the Forest of Dean), and their permission must be obtained before any investigation can be undertaken to intercept these features.

2.10.2 Shrinkable and Swelling Soils

The likely thick Made Ground on-site associated with previous earthworks is likely to consist of colliery spoil which is generally coarse grained. Whilst the underlying glacial soils and weathered Coal Measures may be fine grained, they are likely to be at depth and therefore potential effects are limited.

There are no significant trees on-site, however some may be included as part of the proposed landscape design.

We consider that the potential for shrinkable/swelling soils at shallow depth is Low.

2.10.3 Landslides

There are no recorded landslides in the neighbouring area based on published records.

The site slopes slightly to the west, with a 20 to 25m high steeper slope present at the west boundary. A detailed inspection of this slope was not undertaken due to it being wooded. The proposed buildings are not located close to the slope crest and therefore are unlikely to affect it's long term stability, Changes in surface water or groundwater (e.g. soakaway infiltration) flow may potentially influence it and this will require consideration as part of the design. Excluding changes as a result of the proposed development, we cannot discount future instability on the neighbouring slope, however this is beyond the scope of the investigation and will not be considered further.

The proposed development will involve cut and fill earthworks, however no details of levels have been provided to date. Based on the topography they are unlikely to be significant and require detailed stability consideration. This should be reviewed once further details are provided.

We consider that the potential for landslides is **Low** and no further consideration has been given to this in the report. Once the development design is finalised the low risk should be confirmed.

2.10.4 Compressible Ground

The thick Made Ground soils anticipated beneath the site are potentially compressible, particularly where containing organic materials are present, which could lead to significant settlement at the surface.

We consider that the potential for compressible ground at the site is **Moderate to High**.

2.10.5 Volumetrically Unstable Slag Materials

The potential for volumetrically unstable slag material to be present on the site is not considered in the environmental data report. Slag was a waste product from iron and steel manufacture, and varies chemically depending on the manufacturing process involved. There are three main types of slag, blast furnace slag, basic steel slag and acid steel slag, along with further associated refractory products. Some forms of slags, such as fresh blast furnace slag and acid steel slag, are generally volumetrically stable but, depending on their chemistry, some such as basic steel slags and weathered blast furnace slags can be extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces.

In our experience, on former industrial site such as this, there is the potential for slag materials to be present within the Made Ground. Given the currently available information, we cannot discount that the slag present on site could be volumetrically unstable and we consider that the risk from such instability should be considered **Moderate to High** at this desk study stage.

2.10.6 Historical Underground Structures

Historical information indicates that buildings were formerly located on-site prior to the extensive earthworks that created the current level plateau.

It is unclear whether foundations/underground structures associated with the former buildings remain in the ground.

If the structures are still present, they are likely to be at depth and therefore will likely only need consideration if a deeper foundation solution is required (e.g. piles).

2.10.7 Pyritic Ground

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

Depending on its origin, the Made Ground and underlying glacial soils anticipated beneath the site may also contain elevated levels of pyrite. The Coal Measures bedrock could also contain elevated levels.

Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be **Moderate.**

2.10.8 Unexploded Ordnance

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

A Preliminary (Pre-Desk Study) UXO Desk Study assessment of risk has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix G (Zetica, 2020).

The assessment concludes that '*a detailed desk study, whilst always prudent, is not considered essential in this instance'.*

2.11 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 data report (Appendix C) indicates that the site lies in a radon affected area as defined by the Health Protection Agency, with between 1 and 3% of properties above the action level.

Reference to the UK radon maps published by Public Health England (PHE, 2015) indicates that the site lies in an area classified as a maximum radon potential of between 1 and 3%.

These maps indicate the worst level of radon potential, based on existing information gathered mainly from residential properties within the 1km square in which the site is located. It is designed as a preliminary evaluation only.

Reference to the published BRE guidance in BRE 211 (Scivyer, 2007) indicates that the site lies in a 1km square where the maximum requirements are for no radon protection measures in new buildings (domestic or non-domestic).

Given the currently available information, the risk from radon is considered Low.

3 Preliminary Geo-Environmental Risk Assessment

3.1 Phase One Conceptual Site Model

3.1.1 Background

The Phase One Conceptual Site Model lists the potential sources of geo-environmental risk (both contamination and hazardous gas), the receptors at risk (both human and non-human), and any feasible pathways between the two. These are discussed in the following sections.

3.1.2 Potential Soil Contamination Sources

The site history has indicated that it was part of a steelworks with associated railway land, smithy and spoil heaps which are a potentially contaminative use. In addition, mining occurred on-site and in neighbouring areas. The site was later levelled in the late 1970s/early 1980s to create a level platform with fill likely sourced from these historic activities and other unknown materials.

From the available information, we consider that the following features on site could prove sources of diffuse and point source contamination that could impact on the development, environment or site users:

- Extensive Made Ground – general diffuse contamination with possible localised point sources of contaminated material dependent on the source of the fill;
- Former railway land and industrial uses – point source. However, these would have been at the lower original ground level and not the current site surface;
- Made Ground, Glaciofluvial Deposits and Coal Measures bedrock – potentially contain pyrite, diffuse source.
- Storm sewage materials in the south west portion due to pollution event – point source, however no impact to land was noted. It should be noted that no drainage services appear to be present in this area, therefore this may be a mapping error in the report.
- Demolition arisings associated with the former buildings –they may have contained asbestos containing materials (ACM), diffuse source. These would be at the original ground level and therefore unlikely to pose a risk to activities/occupation at the current site surface.

3.1.3 Potential Contaminants Present

The potential contaminants associated with the above potential sources have been identified from various guidelines published by DEFRA, the Environment Agency and others.

Based on this guidance and our experience, we consider that the following contaminants could be present on the site:

- Heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc);
- Cyanide, sulphate, sulphide;
- Polyaromatic hydrocarbon (PAH) compounds;
- Petroleum hydrocarbons;
- Phenols; and
- Asbestos.

Dependent on the source of the fill materials, additional contaminants may be present and will require consideration if identified.

If the pollution event occurred on-site (unlikely), the presence of contaminants such as E-coli could be possible, however the data report does indicate there was no impact to land. More information on the pollution event should be obtained from the Local Authority/Natural Resources Wales/NRW to confirm the location.

No evidence has been identified from the desk study to suggest that radioactive substances may be present on the site. The potential presence of radon in discussed in Section 0

3.1.4 Potential Sources of Hazardous Ground Gas

This section considers the potential sources of hazardous gases such as methane, carbon dioxide and hydrocarbon vapours. The potential for radon was discussed in Section 0.

Based on the available desk study information, the following potential sources of hazardous ground gas have been identified on, or in close vicinity of, the site:

- Thick Made Ground inc. unknown fill materials – on site source;
- Extensive Made Ground and filling – off-site source;
- Shallow underground mine workings and mine entries – on and off-site source.

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas sources would generally be classified as of very low to moderate gas generation potential.

3.1.5 Potential Receptors

As discussed in Section 1.1, the proposed development will comprise a new primary school. The most vulnerable human receptors with regards to any soil contamination present will be staff and pupils of the school. The children's attendance will be limited and periodic, and the most significant risks are considered to be associated with teachers and caretakers who will have the longest potential exposure to contaminants. Therefore, the school staff (adults) are considered the critical human receptor.

We consider that the most vulnerable receptors with regards to any contamination or hazardous ground gas present are likely to be as follows.

- Future employees, pupils and site visitors, the critical receptors being employees outside.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The water quality in the River Sirhowy located 140m to the south west and closer smaller tributaries.
- The groundwater within the Coal Measures strata beneath the site. Perched water in the shallower Made Ground and glacial soils may be in hydraulic continuity with the deeper aquifers.

3.1.6 Potential Migration Pathways

The proposed development plan includes a mix of hardstanding and landscaped areas.

Based on the Conceptual Site Model discussed in the previous sections, the following are considered the most likely migration pathways with regard to any contamination or hazardous ground gas present beneath the site.

Site Users:

- Ingestion of soils and inhalation of dust in landscaping areas.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.
- Potential exposure to flammable or toxic ground gas/vapours originating from off-site sources – the near surface, likely coarse grained Made Ground may allow free migration of any gas/vapours present.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the shallow soils.
- Ingestion of soils and inhalation of dust across site.
- Dermal contact with contaminated soils.
- Potential explosive risk from flammable or toxic ground gas/vapours from on-site sources.
- Potential explosive risk from flammable or toxic ground gas/vapours from off-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the bedrock and overlying perched water bodies.

River Sirhowy:

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearest surface water course.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential explosive risk from flammable ground gas/vapours from off-site sources.

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified a number of potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

3.2.1 Introduction to Risk Evaluation Methodology

The general 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 by ESP 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, using information known about the site, at this desk study stage. This is presented as Table 3 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 3: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users	Medium – potential for chronic levels.	Low likelihood[2]	Moderate/Low 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	Likely[2]	Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary Aquifers	Likely[2]	Moderate Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
	Leaching of soil contaminants	Impact on River Sirhowy	Medium – site lies 110m from nearest tributary	Low likelihood[2]	Moderate/Low Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely[3]	Moderate 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	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely[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	See Section 7.3.2

Notes:
1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Although thick Made Ground is anticipated, the presence of contamination has yet to be confirmed. Exposure to end users will be limited considering the nature of the development See Section 3.1.
3. Asbestos containing materials may be present in the Made Ground on-site. See Section 3.1.
4. The Made Ground, glacial soils and bedrock can potentially contain sulphates/pyrite. See Section 2.10.7.
5. The thick Made Ground and shallow mine workings are a potential source of hazardous ground gas/vapours. See Section 3.1.4.
6. Radon risk identified in environmental data report. See Section 0.
7. The above risk evaluation is updated following the intrusive investigation and testing in Section 6.2.

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The intrusive investigation was undertaken between the 22nd March and 21st April 2021 in accordance with BS5930:2015.

The investigation was generally designed by the Client to investigate both geo-environmental and geotechnical hazards. It comprised trial pitting, cable percussion boreholes, rotary open hole drilling, measurement of the correlated in-situ CBR value using DCP equipment, soakaway infiltration testing and gas and groundwater monitoring.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2018, and BS EN ISO 14689:2018, along with published weathering schemes.

The investigation point positions are shown on Figure 1.

The ground levels indicated on the investigation point records are approximate only and have been interpolated from the topographical survey provided by the Client. The coordinates shown on the investigation point records were surveyed on-site with a GPS device with a margin of error of up to 3 to 5m.

4.1.2 Investigation Strategy

The majority of the investigation scope was designed by the Client. We understand cable percussion and rotary boreholes were positioned within the proposed building footprint to provide design information and to assess the risks from mining. No investigation was specified in the north portion of the site.

Following the completion of the specified works and the findings, ESP recommended additional rotary drilling to further assess the presence of mine workings beneath the site and associated subsidence risks. These were targeted in the building footprint and in areas of infrastructure e.g. the bus turning circle.

We consider that the investigation undertaken has been sufficient to identify the key ground issues at the site.

4.1.3 Trial Pits

5no. trial pits (CWTP01 to CWTP05) were excavated across the site on 13th April 2021 using a wheeled, backacting hydraulic excavator. The trial pits were excavated to depths of between 1.7m and 2.4m and were terminated to undertake soakaway testing. The trial pit records are presented as Appendix I, and their positions are shown on Figure 1.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.1.4 Cable Percussion Boreholes

5no. 150mm diameter cable percussion boreholes (CWBH01 to CWBH05) were constructed to depths between 9.0 and 12.5m between 22nd to 31st March 2021. The borehole records are presented as Appendix H, and their positions are shown on Figure 1.

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.

100mm diameter thin wall (OS-T/W) open tube samples were collected from the fine-grained soils within the boreholes, where suitable, with a disturbed sample recovered from the open tube cutting shoe. Further small and large plastic tub and bag disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes, as shown on the borehole records.

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 a 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.

Depending on the nature of the test undertaken and the soils subjected to testing, field SPT N-values may require correction before using in design.

Caution must be applied when using in-situ data collected using a solid cone: Much of the existing correlations using N-values obtained from Standard Penetration Tests rely on the energy imposed on a split-spoon sampler (SPT) and not a solid cone (SPT-C). The solid cone has a greater surface area and, therefore, imparts a lower energy per blow than the split-spoon sampler, and can result in an over-estimation of the true SPT N-value. Based on the relationship of energy inputs at the point of penetration (Thorburn 1986), it can be inferred that the equivalent SPT N-value for a test using a cone (SPT-C) is equal to:

$$\text{SPT N-value} = \frac{\text{SPT-C}}{1.869}$$

On completion, monitoring instrumentation was installed in four of the five boreholes as detailed in Section 4.2. Where no instrumentation was constructed, the borehole was backfilled with arisings/gravel.

4.1.5 Rotary Open-hole Drillholes

14no. 100mm diameter rotary percussive open-hole drillholes (CWRH01 to CWRH14), were constructed to depths of between 29 and 40m between 6th and 21st April 2021. The borehole records are presented as Appendix J, and their positions are shown on Figure 1.

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.

The ODEX 115 system of simultaneous drilling and casing was used in the superficial deposits, and the depth of casing in each drillhole is shown on the drillhole records.

Given that the objective of the drillholes was to intercept coal seams/workings, they were constructed under license to the Coal Authority (Permit ref. 21684). In accordance with Coal Authority requirements, given the proximity to occupied properties, water was used as a flushing medium to keep the drill bits cool and return chippings to the surface, and the levels of ground gas were recorded at the drillhole during the drilling works.

Given the distance to the nearest properties was more than 50m, compressed air was used as a flushing medium to keep the drill bits cool and return chippings to the surface. In accordance with Coal Authority requirements, levels of ground gas were recorded at the drillhole during the drilling works. The levels of gas recorded during drilling are presented on the drillhole records.

The drillholes were constructed with the objective of locating the rock-head profile and the depth to coal seams or possible abandoned workings. During the drilling process, the rock chippings returned to the surface were described by the driller and the rate of progress monitored. When large voids were encountered (such as abandoned workings), the drilling rotation was stopped, and the drill rods lowered down the hole and the estimated depth of void recorded. Where voids were encountered, progression beyond proved difficult in some boreholes and therefore the borehole was terminated shorter than the specified depth. It should be noted that, although adequate for identification purposes, the nature of the drilling method does not permit an accurate description of the strata.

On completion, the boreholes were backfilled with bentonite/cement as required by the Coal Authority.

4.1.6 Soakaway Infiltration Testing

The use of Sustainable Drainage (SUDs) systems in Wales, is now regulated and implemented by Statutory Approval Bodies (SABs) within the Local Authority. Applications for SuDS will be reviewed by the relevant SAB which will establish if the application is feasible, suitable for it's intended use and is acceptable for adoption and maintenance by the SAB. All testing is required to be undertaken in strict accordance with BRE Digest 365 (2016) to gain SAB approval.

Soakaway infiltration tests was undertaken in 5no. selected trial pits across the site (CWTP01 to CWTP05). The results of the infiltration testing, and the calculated infiltration rates, are presented in Appendix L. The positions of the test pits are shown on Figure 1.

At each position, the test pit was excavated to a depth which was anticipated to be a possible depth for the soakaway given the ground conditions identified and taking into account any proposed change in ground levels. Clean water was added from a large capacity bowser and the water level monitored as it percolated into the soil.

The infiltration rate was calculated from the time taken for the water to fall between the 75% and 25% full level. Where insufficient time was available for the water level to fall to the 25% full level, but a significant drop in water level was recorded, the infiltration rate can be estimated by extrapolating the test results. However, where the water level only dropped marginally during the available test period (e.g. not as far as the 75% full level), we consider that there is insufficient data to allow a valid extrapolation with any confidence and no infiltration rate can be estimated.

Sufficient time and water were available to repeat the test (a total of three fills) in Test Pits CWTP02, CWTP04 and CWTP05. However, due to the low infiltration rate, insufficient time was available to repeat the test in Test Pits CWTP01 and CWTP03.

Herras fencing was erected around the test pits during the testing to protect site workers/ the general public. On completion of the testing in each pit, any remaining water was removed from the test pit and it was backfilled with the excavated arisings.

4.1.7 Dynamic Cone Penetration (DCP) Testing

CBR testing using the TRL approved dynamic cone penetrometer (DCP) was undertaken at eight positions (DCP01 to DCP08) on 13th April 2021. The testing was undertaken in areas of proposed roads and hardstanding and generally across the site. The test positions are shown on Figure 1, and test results are presented in Appendix M.

The DCP testing was undertaken from the existing ground surface with no service pit excavated. Appropriate precautions were taken during the testing to ensure the safety of ESP operatives.

The DCP test involves the fall of a fixed weight over a fixed height to force a 20mm diameter, 60º cone into the near surface soils. The depth of penetration for varying numbers of blows is recorded and is then converted to a CBR value using well established empirical correlations (Highways Agency, 2008). In general, the tests were undertaken between the existing ground surface and 0.9m below ground level, thus providing a profile of correlated CBR values within the near-surface soils. No water was added to the soils prior to testing, so they were in their natural condition. The correlated CBR values are also shown on the test result sheets in Appendix M.

4.2 Instrumentation

4.2.1 Gas 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 the table below.

Table 4: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
CWBH02	23/03/2021	1.0 – 10.0m	Made Ground/Weathered CM	2
CWBH03	25/03/2021	1.0 – 9.0m	Made Ground/Weathered CM	2
CWBH04	26/03/2021	1.0 – 5.0m	Made Ground	3
CWBH05	31/03/2021	1.0 – 3.0m	Made Ground	3

Notes:
1. Details of each monitoring well are presented on the individual borehole records (Appendix H).
2. Well installed in Made Ground and across the interface with the underlying weathered bedrock.
3. Well installed in Made Ground only.

4.2.2 'Spot' Gas Monitoring

Monitoring of the installed gas wells has been 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.

As discussed in Section 3.1.4, the identified gas sources are classified as being of very low to moderate gas generation potential. The proposed development of a school is classified as of moderate to low sensitivity in terms of gas risk. Therefore, based on the guidelines in CIRIA C665, a minimum of 6no. monitoring visits are required over a 3 month period.

To date, the installed wells have been monitored for levels of groundwater and ground gas on four occasions (once during the fieldworks and three post). The results of the 'spot' gas and groundwater monitoring undertaken to date are presented in Appendix K.

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.

Following measurement of gas levels and flow rates, the well cap was removed, and groundwater levels were measured using a dipmeter from the site surface.

4.3 Sampling Strategy

4.3.1 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 (see Section 4.6).

A non-targeted, random sampling strategy was used to obtain representative information on soil contamination across the site as a whole.

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.

4.3.2 Groundwater Sampling

In order to establish the groundwater quality beneath the site, samples of groundwater were collected from the installed wells on 13th April 2021 during the fieldworks in general accordance with BS ISO 5667-11 (2009).

Only CWBH04 had sufficient water to sample. All other wells were dry or wet at the base. Prior to sampling CWBH04, the wells were purged by the removal of three well volumes where practical, to obtain a water sample representative of the groundwater in the vicinity.

Since the original sampling visits there has been insufficient water to allow sampling. Additional water samples will be obtained (if possible) as part of future monitoring visits.

All groundwater samples taken for possible laboratory chemical analysis were collected in suitable clean containers provided by the testing laboratory for (e.g. clean polyethylene jars/bottles with fitted lids for routine soil testing, clear or amber glass bottles with screw on air-tight caps for organic contaminants, glass vials for volatile contaminants, etc.). Immediately after collection the samples were placed in sealed cool boxes with an ice pack where they remained during storage and transport to the laboratory.

4.4 Evidence of Site Contamination Found During Site Works

No direct visual/olfactory evidence of contamination was identified in the exploratory holes. However, thick Made Ground was present across the site which can contain elevated levels of contaminants such as metals and polyaromatic hydrocarbon (PAH) compounds.

4.5 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 N.

- Natural moisture content.
- Atterberg limits.
- Particle size analysis.
- Loss on ignition, calorific value.
- Compaction testing.
- Single stage undrained unconsolidated triaxial test.

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). Due to the potential presence of pyrite in the soils (see Section 2.10.7), these samples were also analysed to determine the levels of total sulphur, acid soluble sulphate 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 O.

4.6 Geo-environmental Laboratory Testing

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

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.

The laboratory testing suites were specified by the Client.

4.6.1 Soil Samples

To allow an assessment of the potential chronic risks posed to human health, a total of 22no. selected samples of the Made Ground have been analysed for the testing suite specific by the Client.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, boron, cadmium, total chromium, copper, lead, mercury, nickel, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value, sulphate aqueous extract as SO_4; and
- Total EPH (C10 – C40).

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

4.6.2 Leachate Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from nine samples of Made Ground soil recovered from the exploratory holes. The leachate preparation was carried out in accordance with BS EN 12457, at a 10:1 elluate ratio.

The resulting leachate was analysed for the following determinants:

- Arsenic, boron, cadmium, total chromium, copper, lead, mercury, nickel, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Total EPH (C10 – C40).

The results of the leachate tests are presented in Appendix O.

4.6.3 Groundwater Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of groundwater recovered from selected wells have been analysed for the following determinands:

- Arsenic, boron, cadmium, total chromium, copper, lead, mercury, nickel, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Total EPH (C10 – C40).

One samples of groundwater collected from CWBH04 during the first monitoring visit has been analysed and the results are presented in Appendix P. Further samples will be attempted to be obtained as part of future monitoring.

4.6.4 Waste Acceptance Criteria (WAC) Testing

In order to assess the disposal options for the site arisings in term of landfill, the soils have been classified in terms of hazardous/inert waste by analysing leachate generated from five samples of Made Ground soils likely to require excavation and removal from the site, in accordance with the Landfill Directive (2004) – Waste Acceptance Criteria (WAC) testing.

A single strengths of leachate was generated from the soil (at 1:10 concentration) which was analysed for the following determinands:

- Total organic carbon, loss on ignition, pH, acid neutralisation capacity, total dissolved solids, dissolved organic carbon.
- BTEX, PCBs (7 congeners), mineral oil (C_{10}-C_{40}), PAHs, phenol index.
- Arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc.
- Chloride, fluoride, sulphate (as SO_4).

The results of the WAC testing are presented in Appendix O.

5 Development of the Revised Conceptual Model

5.1 Conceptual Ground Model - Geology

The exploratory holes have identified the site to be generally underlain by a thick covering of fine and coarse grained colliery spoil Made Ground followed by Coal Measures bedrock. These strata are discussed in more detail in the following sections. Geological cross sections of the bedrock strata are presented as Figure 2.

Made Ground: encountered to a maximum depth of 14.0m, generally as loose to very dense, grey, sandy, clayey, gravel with occasional horizons of sandy, gravelly, clay. A low mudstone cobble content was noted. The deposits consist of colliery spoil with the gravel predominantly consisting of mudstone. Localised carbonaceous rich layers were noted in the trial pits (e.g. CWTP03 and CWTP05). The Made Ground appears to generally increase in thickness in a northerly direction.

Laboratory testing within the fine-grained colliery spoil indicated liquid limits between 29 and 41%, plasticity indices between 9 and 17%, and natural moisture contents between 11.7 and 23.3%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of very low to low shrinkage potential and would be generally classified as clays of low plasticity (CL). One sample from CWTP05 was classified as a silt of intermediate plasticity (CI).

Particle size analyses within the laboratory have indicated the coarse-grained glacial soils to comprise between 33 and 86% gravel, between 6 and 36% sand and between 8 and 40% silt and clay. A sample at 1.0m from CWTP02 recorded 26% cobbles, with the remainder recording 0%. Based on our observations on site, these proportions would appear representative of the in-situ soils, however the cobble content is higher. Field SPT N-values within the soils varied between 6 and in excess of 50.

Possible Weathered Coal Measures bedrock: encountered beneath the Made Ground and above the competent bedrock between depths of 3.3m and 12m. Due to the sample quality in the cable percussion boreholes, it was difficult to confidently determine the nature of these soils and the upper portion could be glacial in origin or re-worked natural soils at the interface with the overlying Made Ground. The soils was generally recovered as a stiff, orangish brown to grey, sandy, gravelly, silty, clay and a clayey/silty gravel. The gravel consisted of possible mudstone/siltstone lithorelicts.

Laboratory testing within the fine-grained soils indicated liquid limits between 23 and 26%, plasticity indices between 7 and 10%, and natural moisture contents between 8 and 11%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of very low shrinkage potential and would be generally classified as clays of low plasticity (CL)

Particle size analyses within the laboratory have indicated the coarse-grained glacial soils to comprise between 20 and 28% gravel, between 26 and 28% sand and between 44 and 54% silt and clay. No cobbles were recorded. Based on our observations, these proportions would appear representative of the in-situ soils. Field SPT N-values within the soils varied between 12 and in excess of 50.

Coal Measures Bedrock: encountered in the rotary drillholes generally as interbedded mudstones, sandstones and coal seams to a depth of 40m. No ironstones were recorded by the driller, however openhole methods do not permit accurate description. Field SPT N-values were in excess of 50.

Coal seams and evidence of mine workings was consistently encountered in the boreholes and the details are summarised in Table 5 below along with a summary of the other strata encountered.

The boreholes are ordered relative to their location on-site, progressing from the north west to the south east in accordance with the dip of the stratigraphy.

Table 5 - Summary of Ground Conditions and Mine Workings Evidence

RO Number	Depth From	Depth To	Strata Description
CWRH01	8.6m	10.3m	Mudstone
	10.3m	**10.7m**	**Coal (0.4m)**
	10.7m	15.8m	Mudstone
	15.8m	**18.1m**	**Coal (2.3m)**
	18.1m	18.9m	Mudstone - Parting
	18.9m	**19.4m**	**Coal (0.5m)**
	19.4m	24.1m	Mudstone
	24.1m	**24.8m**	**Coal (0.7m)**
	24.8m	40.0m	Mudstone with Sandstone bands.
CWRH09	12.0m	17.0m	Mudstone
	17.0m	**19.5m**	**Coal (2.5m)**
	19.5m	20.5m	Mudstone - Parting
	20.5m	**20.8m**	**Coal (0.3m)**
	20.8m	24.9m	Mudstone
	24.9m	**25.5m**	**Coal (0.6m)**
	25.5m	40.0m	Mudstone
CWRH08	12.5m	16.2m	Mudstone
	16.2m	**17.5m**	**Coal (1.5m)**
	16.2m	19.0m	Mudstone (coal traces between 17.5m and 18.0m) – Parting.
	19.0m	**19.3m**	**Coal (0.3m)**
	19.3m	24.3m	Mudstone
	24.3m	**24.8m**	**Coal (0.5m)**
	24.8m	40.0m	Mudstone
CWRH02	11.3m	16.7m	Mudstone
	16.7m	18.1m	VOID (1.4m) – MINE WORKINGS
	18.1m	29.0m	Normal Drill
CWRH11	8.3m	14.2m	Mudstone
	14.2m	**14.5m**	**Coal (0.4m)**
	14.5m	19.6m	Mudstone
	19.6m	21.0m	VOID (1.4m) – MINE WORKINGS
	21.0m	40.0m	Normal Drill
CWRH10	14.0m	19.2m	Mudstone
	19.2m	**21.0m**	**Coal (1.8m)**
	21.0m	22.0m	Mudstone - Parting
	22.0m	**22.5m**	**Coal (0.5m)**
	22.5m	27.4m	BACKFILL WITH VOIDS (4.9m) –– MINE WORKINGS w/ ROOF COLLAPSE
	27.4m	40.0m	Normal Drill
CWRH03	7.7m	19.6m	Mudstone
	19.6m	**21.7m**	**Coal (2.1m)**
	21.7m	23.0m	Mudstone - Parting
	23.0m	**23.5m**	**Coal (0.5m)**
	23.5m	26.6m	Mudstone with 0.1m thick coal seam (24.7m – 24.8m).
	26.6m	28.7m	VOID (2.1m) – MINE WORKINGS
	28.7m	34.0m	Normal Drill
CWRH04	6.2m	9.3m	Mudstone
	9.3m	**9.6m**	**Coal (0.3m)**
	9.6m	17.1m	Mudstone
	17.1m	**17.8m**	**Coal (0.7m)**
	17.8m	24.2m	Mudstone
	24.2m	**26.2m**	**Coal (2.0m) with 0.2m Mudstone Parting**
	26.2m	33.1m	Mudstone w/ Sandstone (Possible Ironstone) between 32.2m and 32.6m.
	33.1m	**33.5m**	**Coal (0.4m)**
	33.5m	40.0m	Mudstone w/ Sandstone bands

Table 5 (continued) - Summary of Ground Conditions and Mine Workings Evidence

RO Number	Depth From	Depth To	Strata Description
CWRH12	5.5m	10.5m	Mudstone
	10.5m	**11.0m**	**Coal (0.5m)**
	11.0m	18.1m	Mudstone
	18.1m	**19.0m**	**Coal (0.9m)**
	19.0m	23.5m	Mudstone
	23.5m	**24.9m**	**BACKFILL WITH VOIDS (1.4m) - MINE WORKINGS**
	24.9m	40.0m	Normal Drill
CWRH05	5.3m	6.2m	Mudstone
	6.2m	**6.6m**	**Coal (0.4m)**
	6.6m	8.2m	Mudstone
	8.2m	**8.5m**	**Coal (0.3m)**
	8.5m	14.1m	Mudstone
	14.1m	**14.3m**	**Coal (0.2m)**
	14.3m	21.4m	Mudstone
	21.4m	**21.8m**	**Coal (0.4m)**
	21.8m	26.9m	Mudstone
	26.9m	**28.3m**	**VOID (1.4m) – MINE WORKINGS**
	28.3m	31.0m	Normal Drill
CWRH06	5.6m	9.7m	Mudstone
	9.7m	**10.0m**	**Coal (0.3m)**
	10.0m	14.2m	Mudstone
	14.2m	**14.7m**	**Coal (0.5m)**
	14.7m	27.3m	Mudstone with small bands of Sandstone
	27.3m	**27.5m**	**Coal (0.2m)**
	27.5m	28.1m	Mudstone
	28.1m	**29.4m**	**VOID (1.3m) – MINE WORKINGS**
	29.4m	34.0m	Normal Drill
CWRH07	6.2m	11.1m	Mudstone
	11.1m	**12.1m**	**Coal (1.0m) with 0.2m Mudstone Parting**
	12.1m	17.5m	Mudstone
	17.5m	**17.9m**	**Coal (0.4m)**
	17.9m	23.1m	Mudstone
	23.1m	**27.7m**	**VOID (2.5m) and VERY SOFT DRILL (2.1m) – MINE WORKINGS w/ ROOF COLLAPSE**
	27.7m	31.0m	Normal Drill
CWRH13	5.4m	10.7m	Mudstone
	10.7m	**11.0m**	**Coal (0.3m)**
	11.0m	16.0m	Mudstone
	16.0m	**17.0m**	**Coal (1.0m)**
	17.0m	24.5m	Mudstone with small bands of Sandstone
	24.5m	**24.8m**	**Coal (0.3m)**
	24.8m	31.5m	Mudstone
	31.5m	**33.6m**	**Coal (2.1m)**
	33.6m	34.7m	Mudstone - Parting
	34.7m	**35.2m**	**Coal (0.5m)**
	35.2m	40.0m	Mudstone
CWRH14	5.5m	8.0m	Mudstone
	8.0m	**11.5m**	**BACKFILL (3.5m) – MINE WORKINGS**
	11.5m	31.5m	Normal Drill
	31.5m	**34.0m**	**BACKFILL WITH VOIDS (2.5m) – MINE WORKINGS**
	34.0m	40.0m	Normal Drill

Notes:
1. Each borehole summary begins at competent rockhead.
2. All descriptions are by the driller.
3. The full borehole records are presented in Appendix J.
4. Where mine workings have been recorded by the driller, the test is in red and bold.
5. Where the competent rock cover is less than ten times the shallowest workings thickness (the 10T rule) the borehole reference box has been coloured red. The possible weathered rock horizon has not been included a this stage.

Based on the stratigraphy encountered and the published information, coal seam names have been inferred where plausible, however this is tentative only. The names are suggested on the geological cross sections presented as Figure 2.

Two coal seams with a mudstone parting (e.g. 15.8m to 19.4m in CWRH01 and 31.5m to 35.2m in CWRH13) have consistently been encountered beneath the site, progressing to greater depth in a south east direction. We tentatively consider this to be the Yard (Engine) coal seam. Voided and backfilled mine workings were consistently encountered in the top leaf of the seam as demonstrated in the cross section presented as Figure 2.

Generally around 5m beneath this seam, another coal seam was consistently encountered and this may represent the U7FT. Workings were recorded in this potential seam CWRH03 (26.6m to 28.7m) and CWRH10 (22.5m to 27.4m), however these could also represent or include ironstone workings.

Above the Yard Coal seam in the stratigraphy is the Amman Rider and the Bute Coal seams, and these seams have been tentatively identified in the boreholes as thinner individual seams, no obvious mine workings were noted in these seams.

3.5m thick very shallow mine workings were identified in CWRH14. These may represent ironstone workings, however the presence of the L9FT coal seam (indicated to outcrop off-site) also cannot be discounted.

Due to the loss of drilling flush within the shallow workings in some boreholes. the driller could only note changes in strata by monitoring the rate of progress. This has likely resulted in some of the detail in the stratigraphic changes being lost.

Further assessment of mining risk is presented in Section 8.2.2.

5.2 Conceptual Ground Model - Hydrogeology

The investigation did not identify any groundwater in the majority of the exploratory holes.

The groundwater conditions identified in the investigation are summarised in in the table below.

Table 6 - Summary of Groundwater Ingress in the Investigation

Hole ID	Stratum	Comment on groundwater encountered
CWTP01	Made Ground	Slow seepage noted at 1.9m bgl.
CWTP05	Made Ground	Slow seepage noted at 1.4m bgl.
CWBH02	Made Ground/ Weathered CM	No groundwater encountered during construction. Installation wet at base during monitoring to date (around 10m bgl).
CWBH03	Made Ground/ Weathered CM	No groundwater encountered during construction. Installation dry or wet at base during monitoring to date (around 9m bgl).
CWBH04	Made Ground	Water strike at 4.9m bgl. Groundwater monitored between 3.63m and 4.9m bgl to date.
CWBH05	Made Ground	No groundwater encountered during construction. Installation has been dry (around 3m bgl) with the exception of the most recent visit where water was recorded at a depth of 2.53m bgl.
Notes: 1. Full details of groundwater ingress presented on exploratory hole records in the appendices.		

Based on the above findings and the Conceptual Ground Model, we consider that the main groundwater body beneath the site is within the bedrock. However, localised perched water bodies appear to be present within the Made Ground.

5.3 Site Instability

5.3.1 Global Site Stability

No obvious evidence of any global instability issues were noted on the site.

Inspection of the wooded slope was not undertaken.

5.3.2 Excavation Stability

During the excavation of the trial pits, instability and collapse was experienced in the pit walls, particularly upon the introduction of water for soakaway testing.

5.3.3 Mining Hazard

As discussed in Section 5.1 and presented in Table 5, the investigation has identified potential coal and ironstone mine workings beneath the site at shallow depth. Based on the thickness of the shallow mine workings in some boreholes (including those beneath the proposed building e,g, CWRH10, CWRH03 and CWRH11), and using the well accepted 10T general rule for subsidence risk, there is insufficient rock cover above the workings to prevent a crown hole migrating to the surface.

Whilst no obvious evidence of mine workings have been recorded in the same coal seams in nearby boreholes, this does not confirm their absence in these areas. The borehole may have simply progressed through a coal pillar left to support the roof, with workings located in areas adjacent. Abandonment plans should be obtained to gain an appreciation of their extent, however workings often extend beyond these. Until proven otherwise through gridded proof drilling, it will be sensible to assume that workings extend beneath the entire site in these seams and some form of remedial action will be needed.

Where workings are very thick e.g. 4.9m in CWRH10, it is likely that some roof collapse (subsidence) has already occurred above the workings. Thick workings associated with the indicated spine roads are expected, however their location and depth has yet to be confirmed.

No targeted investigation has been undertaken in the area of the adits indicated in the west portion. The adits are indicated to be untreated and their location and condition will require investigating to confirm remedial requirements. Further assessment of the risk posed by untreated shafts on/adjacent to the development boundary will also be needed, and the layout reviewed according to potential risk zones once known.

A high subsidence risk is posed to the proposed development and this is discussed further in Section 8.2.2.

5.4 Chronic Risks to Human Health – Generic Assessment of Risks

5.4.1 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.

5.4.2 Assessment Criteria

In 2013, CL:AIRE published the Category 4 Screening Levels (C4SL – CL:AIRE, 2013) 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. 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). The C4SL have also only been published for a limited number of contaminants commonly identified in contaminated land risk assessments at present (arsenic, cadmium, chromium VI, lead, benzene, benzo[a]pyrene). However, the C4SL have been published for a range of land uses, including residential, commercial, allotments and two types of public open space.

The C4SL 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). The Welsh Local Government Association and Natural Resources Wales (WLGA/NRW) have confirmed that, '*where the site conditions are applicable to the land use scenarios adopted in their calculation, the C4SL levels can be used as screening tools*' for development site risk assessments (WLGA/NRW, 2017). The C4SL have also been accepted by the NHBC for use as generic screening levels on residential developments in England and Wales (NHBC, 2014). Given this, where available and applicable, the C4SL have been adopted as the Generic Assessment Criteria in this assessment.

Where no C4SL is currently available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) (Nathanail et al, 2015) have been adopted. These assessment criteria adopt updated toxicological data and exposure models, and 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.

Where no C4SL or S4UL is available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) – note several SGV have been withdrawn since originally published. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments – and not public open space).

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).

Details of the Generic Assessment Criteria (GAC) adopted for each contaminant are presented on the assessment tables in the following section.

The proposed development comprises the construction of a new primary school with associated areas of hardstanding and landscaping. There are currently no GAC published for such an end use. The critical receptors for a primary 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.

The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 0.2 to 9.6%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for the majority of the soils at the site.

5.4.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised twenty two samples of Made Ground. At this stage, all samples have been considered across the site as one averaging area. The risks from asbestos are considered further in Section 5.4.4.

The results of the Generic Quantitative Risk Assessment for the proposed development are presented in the tables below. It should be appreciated that if the development were to change, the following assessment should be reviewed and, if necessary, updated.

Table 7 - Generic Assessment of Human Health Risks (Public open space near residential properties)

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	7.0 - 12mg/kg	170mg/kg	C4SL[2]	None of 22
Boron	<0.2 – 0.8mg/kg	290mg/kg	S4UL[4]	None of 22
Cadmium	<0.1 – 0.3mg/kg	555mg/kg	C4SL[2]	None of 22
Chromium (total)[6]	7.9 – 21mg/kg	33,000mg/kg	S4UL[4]	None of 22
Copper	28 – 59mg/kg	44,000mg/kg	S4UL[4]	None of 22
Lead	17 - 46mg/kg	1,300mg/kg	C4SL[2]	None of 22
Mercury[7]	<0.05 – 2.0mg/kg	240mg/kg	S4UL[4]	None of 22
Nickel	17 - 43mg/kg	800mg/kg	S4UL[4]	None of 22
Zinc	52 - 170mg/kg	170,000mg/kg	S4UL[4]	None of 22
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03mg/kg	29,000mg/kg	S4UL[4,9]	None of 22
Acenaphthylene	<0.03mg/kg	29,000mg/kg	S4UL[4,9]	None of 22
Anthracene	<0.03 – 0.04mg/kg	150,000mg/kg	S4UL[4,9]	None of 22
Benzo(a)anthracene	<0.03 – 0.12mg/kg	49mg/kg	S4UL[4,9]	None of 22
Benzo(a)pyrene	<0.03 – 0.07mg/kg	11mg/kg	C4SL[2,9]	None of 22
Benzo(b)fluoranthene	<0.03 – 0.19mg/kg	13mg/kg	S4UL[4,9]	None of 22
Benzo(ghi)perylene	<0.03 – 0.05mg/kg	1,400mg/kg	S4UL[4,9]	None of 22
Benzo(k)fluoranthene	<0.03 – 0.08mg/kg	370mg/kg	S4UL[4,9]	None of 22
Chrysene	<0.03 – 0.19mg/kg	93mg/kg	S4UL[4,9]	None of 22
Dibenzo(a,h)anthracene	<0.03mg/kg	1.1mg/kg	S4UL[4,9]	None of 22
Fluoranthene	<0.03 – 0.16mg/kg	6,300mg/kg	S4UL[4,9]	None of 22
Fluorene	<0.03mg/kg	20,000mg/kg	S4UL[4,9]	None of 22
Indeno(123-cd)pyrene	<0.03 – 0.05mg/kg	150mg/kg	S4UL[4,9]	None of 22
Naphthalene	<0.03 – 0.04mg/kg	1,200mg/kg*	S4UL[4,9]	None of 22
Phenanthrene	<0.03 – 0.12mg/kg	6,200mg/kg	S4UL[4,9]	None of 22
Pyrene	<0.03 – 0.12mg/kg	15,000mg/kg	S4UL[4,9]	None of 22
Other Organic Compounds				
Phenol	<0.3 – 0.3mg/kg	280mg/kg	S4UL[4,9]	None of 22
EPH (C10 – C40)	<10 - 30mg/kg	*No Guideline Value Available*		

Notes:

1. Assessment for public open space near residential properties.
2. C4SL: Category 4 Screening Level, published by CL:AIRE.
3. SGV: Soil Guideline Value published by Environment Agency.
4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers.
7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
8. GAC for inorganic mercury adopted.
9. GAC for organic compounds based on 1% soil organic content.
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix O.

* GAC exceeds solubility or vapour saturation limit.

Table 8 - Generic Assessment of Human Health Risks (Commercial Use)

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	7.0 - 12mg/kg	640mg/kg	640mg/kg	None of 22
Boron	<0.2 – 0.8mg/kg	240,000mg/kg	240,000mg/kg	None of 22
Cadmium	<0.1 – 0.3mg/kg	410mg/kg	410mg/kg	None of 22
Chromium (total)[6]	7.9 – 21mg/kg	8,600mg/kg	8,600mg/kg	None of 22
Copper	28 – 59mg/kg	68,000mg/kg	68,000mg/kg	None of 22
Lead	17 - 46mg/kg	2,330mg/kg	2,330mg/kg	None of 22
Mercury[7]	<0.05 – 2.0mg/kg	3,600mg/kg	3,600mg/kg	None of 22
Nickel	17 - 43mg/kg	1,800mg/kg	1,800mg/kg	None of 22
Zinc	52 - 170mg/kg	730,000mg/kg	730,000mg/kg	None of 22
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03mg/kg	84,000mg/kg*	S4UL[4,9]	None of 22
Acenaphthylene	<0.03mg/kg	83,000mg/kg*	S4UL[4,9]	None of 22
Anthracene	<0.03 – 0.04mg/kg	520,000mg/kg	S4UL[4,9]	None of 22
Benzo(a)anthracene	<0.03 – 0.12mg/kg	170mg/kg	S4UL[4,9]	None of 22
Benzo(a)pyrene	<0.03 – 0.07mg/kg	76mg/kg	C4SL[2,9]	None of 22
Benzo(b)fluoranthene	<0.03 – 0.19mg/kg	44mg/kg	S4UL[4,9]	None of 22
Benzo(ghi)perylene	<0.03 – 0.05mg/kg	3,900mg/kg	S4UL[4,9]	None of 22
Benzo(k)fluoranthene	<0.03 – 0.08mg/kg	1,200mg/kg	S4UL[4,9]	None of 22
Chrysene	<0.03 – 0.19mg/kg	350mg/kg	S4UL[4,9]	None of 22
Dibenzo(a,h)anthracene	<0.03mg/kg	3.5mg/kg	S4UL[4,9]	None of 22
Fluoranthene	<0.03 – 0.16mg/kg	23,000mg/kg	S4UL[4,9]	None of 22
Fluorene	<0.03mg/kg	63,000mg/kg*	S4UL[4,9]	None of 22
Indeno(123-cd)pyrene	<0.03 – 0.05mg/kg	500mg/kg	S4UL[4,9]	None of 22
Naphthalene	<0.03 – 0.04mg/kg	190mg/kg*	S4UL[4,9]	None of 22
Phenanthrene	<0.03 – 0.12mg/kg	22,000mg/kg	S4UL[4,9]	None of 22
Pyrene	<0.03 – 0.12mg/kg	54,000mg/kg	S4UL[4,9]	None of 22
Other Organic Compounds				
Phenol	<0.3 – 0.3mg/kg	760mg/kg	S4UL[4,9]	None of 22
EPH (C10 – C40)	<10 - 30mg/kg	*No Guideline Value Available*		

Notes:
1. Assessment for commercial/industrial land use.
2. C4SL: Category 4 Screening Level, published by CL:AIRE.
3. SGV: Soil Guideline Value published by Environment Agency.
4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers.
7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
8. GAC for inorganic mercury adopted.
9. GAC for organic compounds based on 1% soil organic content.
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix O.

* GAC exceeds solubility or vapour saturation limit.

All the determinands analysed were below their respective GACs for both end use scenarios. No further statistical analysis is warranted.

5.4.4 Asbestos

No evidence of asbestos was identified in the samples analysed.

5.5 Risk to Controlled Waters - Level One/Two Assessment

5.5.1 Methodology

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006). Levels of leachable contamination within the soil samples recovered at the site have been analysed, which represents a 'Level One' risk assessment (Carey et al, 2006). In addition, levels of contaminants within the groundwater (albeit one sample) have been analysed, which represents a 'Level Two' risk assessment (Carey et al, 2006).

5.5.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

The Preliminary Risk Assessment (Section 3) has identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The groundwater within the Coal Measures bedrock which is classified as a Secondary A aquifer, where the groundwater could be abstracted for potable use in the future.
- The water within the River SIrhowy, located some 140m to the south west. The groundwater within the shallow soils beneath the site may be in hydraulic connection with the river water.

Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the groundwater beneath the site and the water within the River Sirhowy, and our assessment has concentrated on these receptors.

Surface Water Receptors:
In order to assess the potential impact on the waters of the River Sirhowy, the levels of contaminants have been compared to the Environmental Quality Standards (EQS) published within the Water Framework Directive Directions (WFD, 2015). For the purposes of this assessment, the Annual Average (AA) or long term (mean) EQS have been adopted which represent the acceptable levels of a contaminant over an annual period. Given the most vulnerable receptor is considered to be the River Sirhowy, the EQS published for fresh water have been adopted.

For cadmium, the EQS are dependent on the hardness of the receptor water body. The most stringent EQS value has been used for this assessment. For zinc the EQS is calculated from the ambient background concentration in the local river catchment (WFD, 2015). The River Sirhowy is not listed, therefore the value for all other freshwaters has been used.

Groundwater as a General Resource:
In order to assess the potential risk to groundwater as a general resource beneath the site, we have adopted the '*concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided'* published by UKTAG (2016) have been adopted as assessment criteria. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water, so may be conservative in this instance. Therefore, an exceedance may not necessarily indicate an unacceptable risk.

Hazardous Substances:
Some contaminants which can impact on controlled waters have been classed as hazardous substances (JAGDAG, 2019) and include arsenic, lead, mercury, and some of the polyaromatic and

petroleum hydrocarbon compounds. Natural Resources Wales (NRW) require that the entry of hazardous substances into controlled waters is phased out, or at least any further entry should be minimised. The remaining contaminants are classed as non-hazardous. The classification of each determinand analysed is presented in the assessment tables.

Petroleum Hydrocarbons:
The Environment Agency/NRW have previously stipulated an assessment criteria of 10μg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria for the EPH results as part of this assessment. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

5.5.3 Assessment of Leachate Test Results

The samples selected for leachate testing comprised Made Ground. The results of the leachate testing and their comparison to the relevant assessment criteria are presented in the tables below.

Table 9 - Level One Controlled Waters Risk Assessment – Leachate Results (River Sirhowy)

Compound	Range Recorded	EQS - AA	Exceedances
Metals and Semi-metals:			
Arsenic[1]	<0.16 – 1.30μg/l	50μg/l	None of 9
Cadmium[2,4]	<0.03μg/l	0.08μg/l	None of 9
Chromium[1,5]	<0.25 – 0.88μg/l	3.4μg/l	None of 9
Copper[2]	**0.4 – 2.2μg/l**	**1.0μg/l**	**3 of 9**
Lead[1]	**<0.09 – 3.80μg/l**	**1.2μg/l**	**1 of 9**
Nickel[2]	<0.5 – 0.6	4.0μg/l	None of 9
Zinc[2,6]	<1.3 – 12μg/l	12.3μg/l	None of 9
Polyaromatic Hydrocarbons			
Anthracene[1]	<0.01 – 0.03μg/l	0.1μg/l	None of 9
Benzo[a]pyrene[1]	<0.01μg/l	0.00017μg/l	None of 9
Naphthalene[2]	<0.05 – 0.13μg/l	2.0μg/l	None of 9
Fluoranthene[1]	**<0.01 – 0.06μg/l**	**0.0063μg/l**	**8 of 9**
Other Contaminants			
Cyanide[4]	<40μg/l	1.0μg/l	None of 9
Phenol[4]	<100μg/l	7.7μg/l	None of 9

Notes:
1. Hazardous substance (JAGDAG, 2019).
2. Non-hazardous substance (JAGDAG, 2019).
3. Iron not classified by JAGDAG 2019.
4. Cadmium EQS based on hardness of <40mg/l $CaCO_3$.
5. All chromium present assumed to be chromium VI (conservative approach).
6. Zinc EQS based on ambient background concentration in catchment.
7. Based on River Sirhowy as main receptor.
8. EQS-AA – Environmental Quality Standard (estuarine/saline waters) - Annual Average or Mean.
9. Exceedances indicated in bold and colour coded as shown.
10. Where levels are below detection they are not considered to be elevated above the acceptance criteria.
11. Test results presented in Appendix O.

Table 10 - Level One Controlled Waters Risk Assessment – Leachate Results (General Groundwater)

Compound	Range Recorded	UKTAG[5]	Exceedances
Metals			
Arsenic[1]	<0.16 – 1.30µg/l	5.0µg/l	None of 9
Chromium VI[2,3]	<0.25 – 0.88µg/l	5.0µg/l	None of 9
Lead[1]	<0.09 – 3.80µg/l	5.0µg/l	None of 9
Mercury[1]	<0.01µg/l	0.5µg/l	None of 9
Polyaromatic Hydrocarbons			
Anthracene[1]	<0.01 – 0.03µg/l	0.05µg/l	None of 9
Benzo[a]pyrene[1]	<0.01µg/l	0.005µg/l	None of 9
BbF[1]	<0.01 – 0.01µg/l	0.05µg/l	None of 9
BghiP[1]	<0.01µg/l	0.05µg/l	None of 9
BkF[1]	<0.01µg/l	0.05µg/l	None of 9
IDP[1]	<0.01 – 0.02µg/l	0.05µg/l	None of 9

Notes:
1. Hazardous substance (JAGDAG, 2019).
2. Non-hazardous substance (JAGDAG, 2019).
3. All chromium present assumed to be chromium VI (conservative approach).
4. Assessment based on non-potable groundwater beneath the site.
5. UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only.
6. Exceedances indicated in bold and colour coded as shown.
7. Test results presented in Appendix O.

Key to PAH compounds:
BbF: benzo[b]fluoranthene
BkF: benzo[k]fluoranthene
BghiP: benzo[ghi]perylene
IDP: indeno[123-cd]pyrene

All levels were below the groundwater standards.

Isolated slightly elevated levels of copper and lead were identified relative to surface water standards. Whilst the levels of fluoranthene were low, they were above the stringent guideline level.

The Environment Agency/NRW have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons. This only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk. The levels of EPH were between <10 and 120ug/l. It should be noted that EPH can commonly include natural mineral oils and therefore the values recorded may not be representative of petroleum hydrocarbon contamination.

Whilst the limits of detection are above the guideline levels for cyanide and phenol, no obvious contamination in this regard was observed.

5.5.4 Assessment of Groundwater Test Results

One sample of groundwater has been analysed on one occasion from CWBH04. If possible, additional samples will be attempted to be obtained as part of future monitoring.

The results of the groundwater testing and their comparison to the relevant assessment criteria are summarised in the table below.

Table 11 - Level Two Controlled Waters Risk Assessment – Groundwater Result (River Sirhowy)

Compound	Range Recorded	EQS - AA	Exceedances
Metals and Semi-metals:			
Arsenic[1]	0.40µg/l	50µg/l	None of 1
Cadmium[2,4]	<0.03	0.08µg/l	None of 1
Chromium[1,5]	<0.25µg/l	3.4µg/l	None of 1
Copper[2]	0.7ug/l	1.0µg/l	None of 1
Lead[1]	0.09ug/l	1.2µg/l	None of 1
Nickel[2]	1.9ug/l	4.0µg/l	None of 1
Zinc[2,6]	<1.3ug/l	12.3µg/l	None of 1
Polyaromatic Hydrocarbons			
Anthracene[1]	<0.01µg/l	0.1µg/l	None of 1
Benzo[a]pyrene[1]	<0.01µg/l	0.00017µg/l	None of 1
Naphthalene[2]	<0.05ug/l	2.0µg/l	None of 1
Fluoranthene[1]	**0.02ug/l**	**0.0063µg/l**	**1 of 1**
Other Contaminants			
Cyanide[4]	<40ug/l	1.0µg/l	None of 1
Phenol[4]	<100ug/l	7.7µg/l	None of 1

Notes:

1. Hazardous substance (JAGDAG, 2019).
2. Non-hazardous substance (JAGDAG, 2019).
3. Iron not classified by JAGDAG 2019.
4. Cadmium EQS based on hardness of <40mg/l $CaCO_3$.
5. All chromium present assumed to be chromium VI (conservative approach).
6. Zinc EQS based on ambient background concentration in catchment.
7. Based on River Sirhowy as main receptor.
8. EQS-AA – Environmental Quality Standard (estuarine/saline waters) - Annual Average or Mean.
9. Exceedances indicated in bold and colour coded as shown.
10. Where levels are below detection they are not considered to be elevated above the acceptance criteria.
11. Test result presented in Appendix P.

Table 12 - Level Two Controlled Waters Risk Assessment – Groundwater Result (General Groundwater)

Compound	Range Recorded	UKTAG[5]	Exceedances
Metals			
Arsenic[1]	0.40µg/l	5.0µg/l	None of 1
Chromium VI[1,3]	<0.25µg/l	5.0µg/l	None of 1
Lead[1]	0.09µg/l	5.0µg/l	None of 1
Mercury[1]	<0.01µg/l	0.5µg/l	None of 1
Polyaromatic Hydrocarbons			
Anthracene[1]	<0.01µg/l	0.05µg/l	None of 1
Benzo[a]pyrene[1]	<0.01µg/l	0.005µg/l	None of 1
BbF[1]	<0.01µg/l	0.05µg/l	None of 1
BghiP[1]	<0.01µg/l	0.05µg/l	None of 1
BkF[1]	<0.01µg/l	0.05µg/l	None of 1
IDP[1]	<0.01µg/l	0.05µg/l	None of 1

Notes:

1. Hazardous substance (JAGDAG, 2019).
2. Non-hazardous substance (JAGDAG, 2019).
3. All chromium present assumed to be chromium VI (conservative approach).
4. Assessment based on non-potable groundwater beneath the site.
5. UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only.
6. Exceedances indicated in bold and colour coded as shown.
7. Test result presented in Appendix P.

Key to PAH compounds:

BbF: benzo[b]fluoranthene
BghiP: benzo[ghi]perylene
BkF: benzo[k]fluoranthene
IDP: indeno[123-cd]pyrene

The level of fluoranthene was slightly above detection and above the stringent EQS guideline value.

All other levels were below the EQS and groundwater quality guidelines.

The Environment Agency/NRW have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons. This only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk. The levels of EPH were <10ug/l. It should be noted that EPH can commonly include natural mineral oils and therefore the values recorded may not be representative of petroleum hydrocarbon contamination.

5.6 Hazardous Ground Gas

5.6.1 Degradation of Organic Materials

Gas wells have been installed in four boreholes at the site, and monitored for hazardous gases on four occasions (including once during the fieldworks). Three post fieldworks visits are still to be completed.

Elevated levels of carbon dioxide and positive gas flows have been encountered.

A full assessment of gas risks will be presented in a gas addendum report on completion of the monitoring.

5.7 Sulphate Attack

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

5.7.1 Classification of Site

Due to the presence of Made Ground on the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

5.7.2 Groundwater Setting

Localised perched water was encountered in the exploratory holes and installed wells in the shallow soils. Therefore, groundwater has been considered as mobile in this assessment.

5.7.3 Sulphate Levels

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground and underlying natural soils to be between <10 and 54mg/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.

One groundwater sulphate level of 20mg/l was recorded from the single sample tested.

Levels of acid soluble sulphate varied between 0.02 and 0.06% and total sulphur between 0.01 and 0.07%. From these results, the calculated levels of total potential sulphate are between 0.03 and 0.21%, and oxidisable sulphides are between zero and 0.18%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present.

pH values in the Made Ground varied between 5.3 and 7.9, indicating near neutral to slightly acidic soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

5.7.4 Foundation Concrete Design:

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

Water soluble sulphate:	39mg/l;
Groundwater sulphate:	20mg/l;
Total potential sulphate:	0.17%;
pH value:	5.6

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The site history has indicated that it has been developed as part of an iron works with associated buildings, railway land and spoil heaps which are a potentially contaminative use. Mining has also occurred on-site. The site was later levelled to create a development platform.

The investigation in the specified areas has confirmed thick Made Ground up to a maximum depth of 14.0m consisting of colliery spoil. No obvious visual or olfactory evidence of contamination was noted.

Laboratory testing has identified low levels of soil contamination with respect to the commercial and more stringent residential public open space general acceptance criteria.

No asbestos was recorded in the twenty two samples tested.

The levels of leachate and groundwater (in one sample) were below all groundwater quality standards. Isolated slightly elevated leachate levels of copper and lead were identified relative to surface water standards. Whilst the leachate and groundwater levels of fluoranthene were low, they were above the stringent EQS guideline level.

The current monitoring has recorded levels of carbon dioxide with positive gas flow rates.

No targeted investigation was undertaken in the area of the alleged pollution event in the data report. We recommend further information is sought to support that it did not occur on-site.

No investigation has been undertaken in the north portion of the development area.

6.2 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 3, Section 3.2.2) have been updated and revised in the table below following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 13 - 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	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users	Medium – potential for chronic levels.	Unlikely[2]	Low Risk	See Section 7.1.2 for further discussion.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Likely[2]	Low Risk	See Section 7.1.4 for further discussion.
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary Aquifers	Unlikely[3]	Low Risk	See Section 7.2 for further discussion.
	Leaching of soil contaminants	Impact on River Sirhowy	Medium – site lies 110m from nearest tributary	Unlikely[3]	Low Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low likelihood[4]	Moderate/Low Risk	See Section 7.1.1 for further discussion.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Low likelihood[5]	Low Risk	See Section 0 for further discussion.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely[6]	High Risk	See Section 7.3 for further discussion.
	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[7]	Low Risk	See Section 7.3.2 for further discussion.

Notes:
1. This table updates Table 3 in Section 3.2.2 using results of the investigation. Methodology and details of risk consequence, probability and category presented in Appendix A.
2. All levels below the Generic Assessment Criteria for a commercial and public open space end use.
3. Levels of leachate and groundwater (in one sample) were below all groundwater quality standards. Slightly elevated leachate levels of copper and lead and leachate and groundwater levels of fluoranthene were above surface water guidelines.
4. No asbestos identified in the soils samples tested.
5. Low levels of sulphates recorded, however the Made Ground is slightly acidic.
6. Levels of methane and carbon dioxide identified in monitoring of installed gas wells. Further monitoring to be undertaken.
7. Radon risk identified in data report (see Appendix C).

7 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 the Land contamination risk management (LCRM) guidelines (formerly 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.

7.1 Risks to Health

7.1.1 Asbestos

No evidence of asbestos was detected in the investigated areas. However, it cannot be discounted that the fill material used as part of historic earthworks may have contained asbestos containing materials (ACM).

Whist we consider the shallow soils are likely similar in nature and contamination status, we recommend confirmatory testing is undertaken in the north portion to confirm the absence of asbestos.

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.

The following sections presume that any risks from asbestos materials at the site are mitigated.

7.1.2 Site End Users

Assuming an end use of a primary school, the identified levels of soil contamination in the investigated areas are not considered to pose a risk to future site users. Therefore, no specific remedial measures are considered necessary in these areas.

Whist we consider the shallow soils are likely similar in nature and contamination status, we recommend confirmatory testing is undertaken in the north portion to confirm the low risk proven elsewhere.

If any evidence of Made Ground or other contaminated soils is identified during development, further geo-environmental specialist advice should be sought.

7.1.3 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.

7.1.4 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. However, we anticipate that the levels of contamination at the site are not likely to pose a severe acute risk to construction workers or future maintenance workers. Ground workers would need to undertake their own assessment of the risks to their workers.

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.

7.1.5 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.

7.2 Risks to Controlled Waters

The site has had a potential contaminative history and thick Made Ground has been identified. No significant shallow perched groundwater body has been recorded and we consider the groundwater in the Coal Measures is at depth.

No obvious soil contamination has been identified and low levels of soil contamination have been recorded.

The levels of leachate and groundwater (in one sample) were below all groundwater quality standards. Additional sampling will be undertaken if groundwater is recorded as part of future monitoring visits to confirm the low levels initially recorded.

Isolated slightly elevated leachate levels of copper and lead were identified relative to surface water standards. Whilst the leachate and groundwater levels of fluoranthene were low, they were above the stringent EQS guideline level. Slightly elevated levels of EPH were also noted, however whether these may not be representative of petroleum hydrocarbon contamination.

Considering the historic and current industrialisation of the wider area, extensive Made Ground of a similar nature would be present and we consider it unlikely that the levels encountered would be considered regionally significant in the context of the area. In addition, the surface water receptors are over 100m from the site and therefore the potential impact (if any) of any minor contamination contribution from the site would be low.

Hardstanding is proposed across some of the site which would limit future infiltration compared to the current surface. Fine grained soils were also identified below the Made Ground and these will likely limit vertical migration of any contamination.

We do not consider remediation is warranted and the risk to controlled waters is likely low. If any contamination is encountered during the construction works, we recommend these are suitably removed or assessed further by a specialist.

Some risk mitigation may be required if soakaways are used to dispose of surface water run-off – see Section 8.8 for further discussion. In addition, we recommend further detail on the pollution incident in the south portion is gained to attempt to confirm it was actually off-site.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

The available results are insufficient to allow a confident assessment of the characteristic situation (C665:2007). At this stage, it is considered likely that gas protection would be required for the development.

On completion of the remaining scheduled gas monitoring visits, we will prepare a gas assessment addendum report, detailing the monitoring results, the recommended characteristic situation and any gas protection required, assessed in accordance with BS8485:2019.

Further gas monitoring will likely be required post completion of the remedial grouting works to ensure the ground gas regime has not changed and that the protection measures provided are adequate.

7.3.2 Risk to the Development – Radon

No radon protection is required.

7.3.3 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. At this stage, we recommend all excavations should be treated as confined spaces and suitable precautions taken prior to man entry.

The above recommendation will be reviewed as part of our ground gas addendum.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

The Made Ground has been identified to contain unburnt colliery spoil, locally including a significant fraction of coal. These materials have the potential to combust, given the correct environment (including a heat source and oxygen). Colliery spoil can ignite spontaneously due to a prolonged heating caused by its proximity to buried electrical cables, and this would be more likely to occur in loosely compacted soils with a high proportion of air voids in which oxygen (which drives the combustion) could be present.

Laboratory testing has indicated soil organic contents between 0.2 and 9.6% and values of loss on ignition between 3.9 and 10%.

The potential for combustion within soils is not a well-established science and only general guidelines are available relating to availability of source material for combustion. Mass loss on ignition (LOI) has also been used as an indicator of combustibility and a value of 25% LOI is commonly considered to be the lower bound for potentially combustible soils (Richard et al, 1993). The loss on ignition percentages reported at the site are all below this value.

Generally, we consider that the colliery spoil at the site is not significantly combustible. Locally we cannot discount that pockets of carbonaceous Made Ground may exist and we recommend where these are encountered they are excavated and replaced or recompacted sufficiently to limit air voids in the soils. All electrical services should also be placed in trenches filled with inert granular fill, thus isolating them from potentially combustible materials. These measures are likely to be sufficient to mitigate the risk of combustion at the development.

7.4.2 Sulphate Attack on Buried Concrete

The following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	39mg/l;
Groundwater sulphate:	20mg/l;
Total potential sulphate:	0.17%;
pH value:	5.6

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-2z, allowing for mobile groundwater.

7.5 Re-Use of Materials/Disposal of Excess Arisings

7.5.1 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:

- Disposed at a licensed landfill;
- Disposed at a licensed, permitted soil treatment centre; or
- 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.

5no. WAC tests have been undertaken and the results are presented in Appendix O.

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.

7.5.2 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.

8 Geotechnical Comments

8.1 Site Preparation and Earthworks

8.1.1 Unexploded Ordnance

As discussed in Section 2.10.8, a specialist preliminary assessment has concluded that '*a detailed desk study, whilst always prudent, is not considered essential in this instance'*. .

Although no special precautions are considered necessary, a careful watch should be maintained during all excavation and any suspected ordnance identified should be investigated further by specialists. Ordnance awareness is recommended during site inductions.

8.1.2 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed/Himalayan Balsam etc. was identified on the site during the site works. However, their growth is seasonal and therefore their presence cannot be discounted.

8.1.3 Existing Foundations and Services

No evidence of old foundations and underground structures have been identified in the investigation. We cannot discount their presence at greater depth, at the original ground level. If any are discovered then they should be grubbed up as part of the site preparation works.

Live services have been identified to encroach on site as described in Section 2.1. Considering the presence of these services, an allowance for diversion/a suitable exclusion zone should be made when planning the development and site works. Further details and permissions may need to be obtained from the provider.

Land drains, if present, may provide a seepage path into excavations. Land drains should be diverted where they enter foundation excavations.

8.1.4 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.

8.1.5 Earthworks

The site is sloping from east to west. We understand that in order to construct a suitable development plateau, ground levels in the east will be lowered, and the excavated soils used as fill to raise ground levels in the west, however specific levels are not currently available.

Whilst it is variable in nature, we consider that the colliery spoil Made Ground would likely be suitable for re-use, however this would be dependent on it's performance requirements (e.g. structural fill vs general fill) and management during the works (due to moisture susceptibility). Once the detailed design is known, the suitability of the Made Ground soils should be assessed. Proving they are suitable, their re-use could enabled with a materials management plan (see Section 7.5).

Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site. Any proposed changes to the topography should reviewed by a geotechnical engineer.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

Following the site investigation the potential geotechnical hazards have been re-assessed as described in the following section. This includes construction risks identified by the intrusive investigation.

For risk associated with poor temporary stability of excavations and groundwater ingress see Section 8.7. For risks associated with sulphate attack see Section 0.

8.2.2 Coal Mining Hazard

8.2.2.1 Underground Mine Workings

The investigation identified abandoned coal workings within ironstones and coal seam between 8.0m and 31.5m depth beneath the site. The workings were voided and backfilled and of up to 4.9m in height based on the rough measurement possible using openhole drilling methods. Based on the available information, we consider that these abandoned workings are likely to pose an unacceptable subsidence risk to the development.

To avoid future failure and provide robust long term certainty of stability in this regard, drilling and grouting will be required beneath the proposed building to treat the mine workings. At this stage, moving the building is unlikely to result in treatment not being required. However, further assessment could be undertaken in this regard, if it is beyond the current investigation area. Rotary drilling should be undertaken in the investigated north portion to confirm the subsidence risks.

A management approach may be considered more practical in external areas which would consists of the incorporation of geogrids/geosynthetics to span potential voids if propagated (see Section 8.3). This should prevent immediate failure and would allow localised repair and treatment, if and when a feature propagated. Even if catastrophic failure does not occur, aerial settlement over the development may occur due to subsidence associated with the workings. If a management approach isn't considered acceptable in areas of higher external risk, drilling and grouting will also be required in these areas.

8.2.2.2 Mine Entries

The adit (possible adits) in the east portion are located beneath the proposed car park. It's/their location and condition should be confirmed prior to determining whether a management strategy is sufficient to mitigate potential risks. Where shafts are located at the boundary, they are likely to be at original ground level. Departure distances should be confirmed by obtaining their individual records and potential collapse zones should be determined. Considering the thick Made Ground, the collapse zones could be large and sterilising these zones from development may not be acceptable. This should be discussed with the design team and then further action determined. Locating them may prove difficult without extensive gridded drilling.

The above action will need to be formalised in a remedial strategy which will need to be submitted and approved by the Local Authority and Coal Authority in advance of it's undertaking.

It should be appreciated that in any area of past mining activity the possibility of the existence of unrecorded mine entries cannot be discounted. During site clearance operations and all excavation, a careful watch should be maintained for any isolated pockets of loose fill, brickwork or other anomalous features which may be indicative of past mining operations. Any such features should be subject to further investigation.

8.2.3 Shrinkage and Swelling

The shallow Made Ground soils are generally coarse-grained in composition and, therefore, should not be affected by seasonal changes in moisture content. Where fine grained soils were locally encountered, the modified plasticity index suggests they are of very low to low shrinkage potential.

No notable trees are present on-site. Whilst no trees are indicated on the proposed development plan we understand this is not a detailed design and therefore they may be incorporated.

A raft foundation is proposed for the development and this will be placed on granular fill (possibly re-worked Made Ground where possible), therefore consideration of the shrinkage potential of localised shallow fine grained soils is unlikely to be required. If the raft foundation design changes or significant planting is proposed further consideration of the localised fine grained Made Ground soils may be needed in accordance with NHBC guidelines.

8.3 Preliminary Foundation Design and Construction

We understand that the site is being considered for potential development as a single storey primary school and the comments and recommendations in this report assume that the development will involve conventional load-bearing brickwork construction. A high mining risk has been identified from underground mine workings and mine entries and these will require remediation prior to finalisation of the foundation design.

Due to the presence of thick Made Ground of variable strength and nature and the potential for differential settlement, we recommend a reinforced raft foundation constructed on compacted fill. This will also limit any future general subsidence associated with the underlying mine workings.

The existing ground should be excavated to a minimum of depth of the order of 1.0m below the proposed bearing level of the main structural foundations. The excavation should be replaced with suitable granular material (e.g. Department of Transport Type 1 sub-base or similar approved) compacted in layers in a controlled manner to a suitable earthworks specification. This ground improvement should be carried out over an area extending to a minimum of 1.0m outside the footprint of each foundation. Thickening of the foundations is likely to be required beneath the columns and any load bearing walls.

Prior to backfilling, the base of the excavation should be proof rolled and inspected by a suitably qualified engineer, and should any soft, compressible or otherwise unsuitable materials be encountered they should be removed and replaced by lean mix concrete or suitable compacted granular material.

Based on the findings of our investigation, we consider that coarse-grained Made Ground soils that would be excavated as part of this treatment may be suitable for re-use as compacted materials beneath the structures. Any unsuitable materials, such as putrescible and contaminated materials, soft, wet soils, large fragments of concrete and masonry etc. would need to be removed prior to placement. Concrete and masonry fragments greater than a nominal 100mm would need to be crushed to make them suitable for use as general structural fill.

The presumed bearing value of the re-compacted fill materials would be dependent on the foundation size, the compacted material type and quality, the compaction characteristics and foundation loading details. Following confirmation of the loadings we can provide further comment in this regard.

Provided the western extent of the building remains in it's current location, we do not anticipate that the proposed loadings will result in adverse effects to the slope on the boundary, however this should be confirmed once the layout and design has been finalised.

8.4 Floor Slab Foundations

If a raft foundation is used, the floor slab will be integral and ground bearing.

The replacement materials beneath the raft should be compacted sufficiently to achieve the required performance specified by the structural designer.

8.5 Retaining Wall Design

We are not aware of any retaining structures being required in the development.

8.6 Pavement Design

We understand that vehicle access roads/hardstanding are proposed at the site.

Considering the shallow mine workings proven, any hardstanding should incorporate geosynthetic reinforcement to manage potential risks associated with any subsidence. In areas where very shallow mine workings have been proven (e.g. the bus turning circle), the Client will need to determine whether a management strategy of the risks will be acceptable, if not drilling and grouting will be needed.

8.6.1 Design CBR Value

An assessment of the likely CBR values in areas of grade (no change in ground level) has been undertaken using a dynamic cone penetrometer (DCP). Testing was concentrated along the proposed access roads. The results of the DCP testing are converted to CBR values using correlations published by the Highways Agency (2008).

The DCP results and the correlated CBR values are presented in Appendix M.

The testing has generally recorded values in excess of 5% for the shallow Made Ground consisting of colliery spoil across the site. However, localised lower values cannot be discounted.

We recommend excavation and replacement/re-compaction of the coarse Made Ground (where suitable) to provide improved and consistent performance. Actual design values should be determined for designated areas as required.

The CBR value of the colliery spoil will be particularly sensitive to changes in moisture content. Careful consideration should be given to whether in the long term, the existing moisture content at which the test was undertaken is appropriate. If the formation were to become wetter the long term Design CBR value would reduce, possibly dramatically. In accordance with the recommendations in IAN73/06 (Highways Agency, 2009a), we recommend that the sensitivity of the Design CBR value of the fine-grained soils to variations in moisture content be assessed by further laboratory testing.

The final sub-grade should be inspected by a qualified engineer, and any soft or loose material removed and replaced as necessary, to ensure that the Design CBR value is achieved. It is further recommended that the sub-grade be proof-rolled with a suitable roller prior to the placement of the sub-base materials.

We consider that it would be prudent to re-measure the CBR values of the sub-grade on exposure to confirm that they are equal to or better than the values measured in this investigation (as recommended by the Highways Agency [HA, 2009a]). If the CBR values in the sub-grade are found to be lower than the Design CBR, the subgrade must be improved to achieve the Design CBR or the road pavement foundation redesigned.

8.6.2 Susceptibility to Frost Action

The near surface fine grained/coarse grained soils are considered to be non-frost susceptible.

8.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators.

During the excavation of the trial pits, instability and collapse was experienced in the pit walls, particularly upon the introduction of water for soakaway testing. Support of excavation sides is likely to be necessary. Should any indication of excavation instability be noted at any depth, support should be provided as appropriate.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 1m depth and below this depth only localised seepages are anticipated. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.8 Soakaway Drainage

8.8.1 Soakaway Design

Soakaway infiltration tests were undertaken in five test pits excavated across the site (CWTP01 to CWTP05). The results of the testing are presented in Appendix L.

The calculated and extrapolated infiltration rates are presented in the table below.

Table 14 - Summary of soakaway infiltration test results

Fill No	Test Pit	Test depth	Measured Infiltration Rate	Infiltration Soils at Base
1	CWTP01	2.2m	*Test Failed*[2]	Fine grained Colliery Spoil
1	CWTP02	2.4m	5.9×10^{-5}m/s	Fine grained Colliery Spoil
2		2.0m	7.8×10^{-5}m/s	
3		1.9m	8.0×10^{-5}m/s	
1	CWTP03	1.7m	*Test Failed*[2]	Coarse grained Colliery Spoil
1	CWTP04	2.0m	2.3×10^{-5}m/s	Coarse grained Colliery Spoil
2		1.6m	2.3×10^{-5}m/s	
3		1.6m	2.0×10^{-5}m/s	
1	CWTP05	2.2m	1.9×10^{-6}m/s	Coarse grained Colliery Spoil
2		2.0m	*Test Failed*[3]	
3		1.4m	5.7×10^{-6}m/s	

Notes:
1. Testing undertaken in accordance with BRE 365. Water level fell to 25% of fill depth.
2. Water level did not fall to 25% fill depth.
3. Pit collapsed during test.

The soakaway results are variable. Infiltration rates in the order of 10^{-5} and 10^{-6}m/s are achievable in the Made Ground, however other tests have failed. This is likely due to variability of the fines present which range between 8 and 40%. Where fine-grained soils are present, infiltration rates will be lower.

The initial testing has indicated that soakaway drainage may be feasible, however testing will need to be undertaken in the specific proposed location to confirm this. In addition, potential regulatory requirements will need to be satisfied and geotechnical implications considered.

8.8.2 Location Considerations

Care should be taken in the siting of the soakaways, with in particular, soakaways should be constructed a minimum of 10m away from the crest of slopes. Once the location is decided the potential effect on the long term stability of the slope on the west boundary should be checked.

Soakaways should not normally be constructed closer than 5 m to building foundations or sensitive structures. We recommend they are constructed as far away as possible, as the inundation of the underlying fill materials could result in collapse compression of the colliery spoil fill materials.

We recommend that the soakaway discharge point is kept as high as possible within the ground to maximise the thickness of soils between the discharge point and the groundwater below, i.e. the attenuation potential of the soils is maximised. The base of the soakaway should be constructed a minimum of 1m above the shallowest groundwater level to ensure long term functionality.

8.8.3 Regulatory Considerations

8.8.3.1 Natural Resources Wales

The infiltration stratum at the site would be the Made Ground, which may have some hydraulic continuity with the underlying bedrock aquifer and the groundwater within is vulnerable to pollution. Infiltration of water into the Made Ground could liberate contamination, however soil levels were low and leachate testing has recorded levels below the acceptance criteria for groundwater quality.

We recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site and if further assessment would be needed to demonstrate a low risk to controlled waters. As a minimum, leachate testing in confirmed soakaway locations and risk mitigation measures such as oil interceptors may be required.

8.8.3.2 Statutory Approval Bodies (SABs)

The use of Sustainable Drainage (SUDs) systems, is now regulated and implemented by Statutory Approval Bodies (SABs) within the Local Authority. Applications for SuDS will be reviewed by the relevant SAB which will establish if the application is feasible, suitable for it's intended use and is acceptable for adoption and maintenance by the SAB.

Whilst adoption and maintenance approval will be the final stage in the process, SAB's will require validation of the constructed SuDS and will utilise commuted sums to ensure the proposed vs as built construction. SAB's will also be tasked with enforcement action in the event SuDS applications are not submitted appropriately or are not constructed as per authorised details.

It should be noted that the SABs process can take up to seven weeks for a complete and properly filed application to be processed and approved, and, if not already made, the application timeline should be considered as part of an any development.

9 Recommendations

We consider that the following further investigation and assessment would be required or prudent prior to development:

Required Further Actions:

- Further investigation and remedial action is required to mitigate the significant mining subsidence risks identified from underground mine workings and mine entries. This will consist of drilling and grouting beneath the building as a minimum and possibly other areas of concern where a management approach may not be considered acceptable due to the likelihood of catastrophic subsidence occurring.
- Remedial and mitigation measures and the management strategy will need to be appropriately designed in accordance with current guidance and be submitted to and approved by the Local Authority and Coal Authority in advance of it's undertaking.
- Additional desk study information should be obtained to design the remedial works including relevant mine entry records and available mining abandonment plans. Risk and collapse zones should be refined based on this information.
- The gas monitoring programme is yet to be completed and three further fortnightly visits are required. The risks to end users and construction workers (confined spaces) and recommended mitigation measures will be presented in our ground gas addendum report. Further gas monitoring will likely be required post completion of the remedial grouting works to ensure the ground gas regime has not changed and that the protection measures provided are adequate.
- Additional perched water samples should be obtained and tested if possible as part of the remaining monitoring.
- Whist we consider the shallow soils are likely similar in nature and contamination status, we recommend confirmatory testing is undertaken in the un-investigated north portion to confirm the low contamination risk proven elsewhere. Additional rotary drilling in this area is also required.
- Provided the western extent of the building remains in it's current location, we do not anticipate that the proposed loadings will result in adverse effects to the slope on the boundary, however this should be confirmed once the layout and design has been finalised.
- Changes in surface water or groundwater (e.g. soakaway infiltration) flow may potentially influence the stability of the slope on the west boundary and this will require consideration as part of the design.
- Localised removal of organic materials were encountered during construction.
- Localised removal of carbonaceous Made Ground to avoid potential combustion risks.

Recommended Further Actions:

- Once earthworks design is finalised, assess suitability of Made Ground for re-use considering performance requirements.
- Re-measure CBR values at sub-grade prior to pavement construction and assess sensitivity of CBR values with changes in moisture content.
- Further testing to BRE365 in confirmed location of soakaway drainage to prove viability.
- Enquiries to NRW to confirm acceptance of soakaways in Made Ground and any risk mitigation measures required (Section 8.8.3).
- Materials management plan for re-use of soils on site and WM3 assessment of soils to be disposed of/re-used off-site.

- No targeted investigation was undertaken in the area of the alleged pollution event in the data report. We recommend further information is sought to support that it did not occur on-site. If evidence indicates it did, further investigation and testing may be required.
- If the raft foundation design changes or significant planting is proposed further consideration of the localised fine grained Made Ground soils may be needed in accordance with NHBC guidelines.

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