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Former Tudor Inn, Cimla, Neath

Proposed Residential Development

Geotechnical and Geo-environmental Assessment

Report Reference: ESP.8398.3830

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Former Tudor Inn, Cimla, Neath
Proposed Residential Development
Geotechnical and Geo-environmental Assessment

Prepared for:
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Report Reference: **ESP.8398.3830**

Revision	Status	Date	Written by	Checked and Approved by
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Contents

Plates

Executive Summary

Tai Tarian Ltd are considering the purchase of the subject site for redevelopment as residential properties. ESP completed a geo-environmental and geotechnical assessment at the site in 2013, and a desk study has been completed by others in 2022. ESP have collated the information available from these reports and updated the 2013 assessment report based on current (2023) guidance and standards. 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)	-	The site is currently occupied by open grassland with the remnants of the former Tudor Inn (as a stockpile).
	Identified Ground Conditions. (Section 5.1)	-	The investigation has indicated very shallow Coal Measures bedrock (less than 0.5m depth) across the site. A thin veneer of Made Ground is present in the north-west (tarmacadam and sub-base), with an area of thicker Made Ground (apparent end tipped fill) on the south-western boundary. The Graigola coal seam was recorded at depths of between 4m (north-west) and 12.5m (eastern margins.
	Groundwater Conditions. (Section 5.2)	-	The site is underlain by a Secondary A Aquifer. Groundwater is not anticipated within 5m of the site surface.
	Historical Land Use. (Section 2.2)	-	The site was formerly rural land until the construction of the Tudor Inn in the 1970s. The Inn was reportedly demolished in 2009 after being damaged by fire.
Geo-environmental	Potential Contamination Sources (Section 3.1.2)	Low	No past contaminative use has been identified. Asbestos is likely to have been present within the former Tudor Inn building.
	Chronic Risks to Human Health (Sections 5.4.3, 5.4.4 and 7.1.2)	Low	Levels of contaminants were generally low across the site. However, an elevated PAH compound was recorded in one pit (TP1) in the east of the site. Asbestos materials were observed within the stockpile and on the surface just to the south-east.
	Risks to Controlled Waters (Section 7.2)	Low	The risks to controlled waters are considered low.
	Hazardous Ground Gas (Section 7.3)	High	Workings within the Graigola coal seam could prove a source of hazardous ground gas. A Detailed Mine Gas Risk Assessment is required, including the installation and monitoring of gas wells in the coal/workings. As a minimum, basic radon protection is required.
	Other Hazards (Section 3.1.3)	Low	Asbestos materials have been observed within the stockpile.
Geotechnical	Abandoned Mine Workings and/or Old Mine Entries (Section 8.2.2 and 8.2.3)	High	Although no mine workings have been recorded to date, we consider it almost inconceivable that the Graigola seam has not been worked in the past beneath the site. If workings are present, there is a high subsidence risk, particularly beneath the north-west and south-western margins of the site. Further investigation is recommended. No mine entries are recorded, but their presence cannot be discounted.
	Weak/Compressible Ground, requiring non-traditional foundations (Sections 8.3.1 and 8.3.2)	Low	Coal Measures bedrock is present at depths of less than 0.5m across much of the site. Raft foundations may be more economic by minimising excavation into hard bedrock. Ground bearing floor slabs are likely to be suitable. Further investigation is recommended to define the lateral extent of the end tipped fill in the south-western margins.
	Shrinkage or Swelling (Section 2.8.1)	Low	The shallow soils are coarse-grained.
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Moderate	Laboratory testing has indicated the site is classed as AC-2z in terms of sulphate attack on buried concrete.
	Soakaway Feasibility (Section 8.8)	-	Soakaways are likely to be feasible in areas of the site. However, siting of soakaways should ensure that site stability is not compromised.
	Other Hazards (Section 8.2.5 and 8.2.6)	High	Very shallow bedrock will impact on excavations/trenches. We recommend careful design of drainage to minimise excavation depths. A geotechnical assessment of the former quarry face beneath the southern margins of the site should be undertaken.

	Potential Hazard	Anticipated Risk	Discussion
Others	UXO (Section 2.8.4)	-	A Preliminary UXO assessment is recommended prior to any further investigation or ground works.
	Flooding (Section 2.4.3)	Low	
	Invasive Plants (Section 8.1.2)	-	Japanese knotweed has been observed on the south-western margins. We recommend a full survey.
	Further Investigation Required?	Yes	See Section 9.0.

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

Tai Tarian Ltd (hereafter known as the Client) are proposing to redevelop the subject site for residential purposes. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, have previously undertaken an intrusive investigation and assessment at the site in 2013 (ESP, 2013). ESP have now been instructed by Spring Design, acting on behalf of the Client, to prepare an update to this previous assessment identifying and evaluating potential ground hazards which could impact on the proposed development. The site location is shown on Insert 1 in Section 2.1.

The proposed development will comprise conventional two-storey residential dwellings with private gardens, landscaping and estate roads. The proposed development layout is presented as Figure 1, and shows a large apartment block in the north-west, with link of three dwellings and seven further residential structures around a central north-west to south-east orientated estate road. A new access road for the development will be constructed from Beacons View to the north-east, created by the demolition of existing properties. An infiltration basin (for SuDS) is shown just to the east of the new access.

Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2020), i.e. conventional structures, with no exceptional risk.

1.2 Objective and Scope of Works

The objective of the investigation was to review available 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 mutually developed with the Client by ESP within an agreed budget, and comprised an update of our previous assessment report from 2013 (ESP, 2013), incorporating updated assessment guidance, criteria and methods and more up-to-date desk study data provided in a desk study report on the site prepared by Integral Geotechnique Wales Limited (IGWL, 2022). It should be appreciated that no new desk study data has been obtained in the preparation of this report. However, a site reconnaissance visit has been undertaken to assess the current status of the site.

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 1st December 2022 (ref: db/8398.lt1 proposal). This updated assessment was prepared in January 2023.

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 BS5930:2020 (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 BS5930:2020. 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.

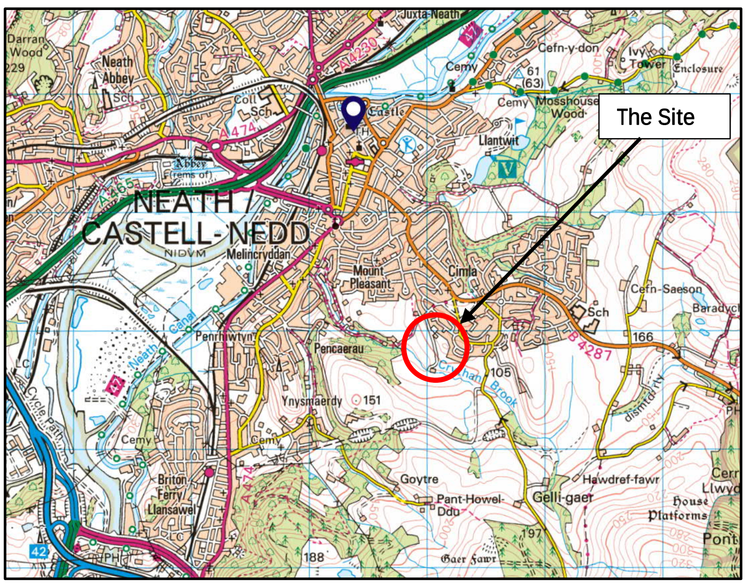
2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps (Appendix B), an environmental data report (Appendix C), a stability report (Appendix D), and a mining report obtained from the Coal Authority (Appendix F) all obtained as part of a recent desk study assessment (IGWL, 2022). 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 site on 17th January 2023 during dry and sunny weather, following a period of heavy rainfall 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 comprises the grounds of the former Tudor Inn, located on the south-western side of Cimla, Neath. The National Grid Reference of the centre of the site is (SS) 276060 196010 and the postcode is believed to SA11 1JA. A Site Location Plan is presented as Insert 1 below.



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

The site is irregular in shape, consisting in the main of a roughly rectangular area around 100m by 60m in size, with a narrow triangular extension running up to the site entrance on Cae Rhys Ddu Road in the north-western margins (see Figure 2 and Plate 1). In total, the site is approximately 0.8 hectares in area.

It is bounded by:

- to the north-east: residential properties on Beacons View;
- to the south-east: open grassed pasture land behind the houses on Beacons View;
- to the south-west: a farm track and open pasture land; and
- to the south: an old sandstone quarry, and derelict building.

The north-western access comprises a tree-lined former, apparently tarmacadam surfaced drive to the former Tudor Inn (Plate 2). The former location of the Tudor Inn structure is now occupied by an overgrown ad-hoc stockpile of the remnants of the demolished structure (see Figure 2 and Plates 3 to 6). The remnants comprise mainly very large fragments of concrete and brickwork, which do not appear to have been crushed. Remnants of the original structure's lower walls appear to remain, suggesting that the old foundations etc remain. Occasional fragments of asbestos cement sheet and possible asbestos insulation were identified amongst the stockpile materials (Plate 7). Further smaller fragments of asbestos cement sheet were observed on the site surface just to the south-east of the stockpile (Plate 8). The stockpile and the immediate area appear to be underlain by a tarmacadam surface.

The majority south-eastern area comprises open grassed landscaping, with dense vegetation (apparently predominantly brambles) on the south-western and north-eastern margins (Plates 9 to 10). A former track to the quarry was identified along the south-western margins in 2013, however, this is no longer evident and is apparently covered with vegetation (Plate 11).

The trees along the margins of the north-west f the site comprise deciduous and coniferous of unknown species. Further trees are evident on the north-eastern and eastern boundaries.

The site lies at the top of a topographical ridge, towards the top of the south-west facing valley sides of the River Neath, with the adjacent land to the south-west sloping away relatively steeply. The land to the north-east also slopes away from the site, albeit at a lower gradient, so that the houses on Brecon View are at a slightly lower elevation than the site. We are not aware of a topographic survey for the site at this time but, from visual observations, the south-eastern margins of the open grassed area appear to form the topographical high at around 116m OD, with the ground to the north-east sloping gently down towards to the houses. The area around the former Tudor Inn and its driveway appears relatively flat and level. The south-western margins of this area comprises a steep downslope to a farm track (Plate 12), of around 3 to 4m height (visually estimated) around the former building. The south-western margins of the open grassed area further to the south-east also appears to comprise a downslope, however this is currently obscured by the dense vegetation – in 2013, this downslope was visually estimated to be around 3m in height. Although obscured by vegetation, the sub-vertical face of the former quarry appears to remain in the southern margins of the site.

Vehicular access to the site is currently gained via the original site entrance off Cae Rhys Ddu Road, which is now blocked by large boulders. The boundaries with the residential properties to the north-west generally comprise post and wire or wooden fences, with dry stone walls apparent along the south-eastern and south-western boundaries (in places). Evidence of Japanese Knotweed has been reported along the lower-lying, south-western boundary of the site.

Service plans were obtained by ESP from the utility companies in 2013 – copies of this service information are presented in Appendix L at the rear of this report. Site observations and these utility plans suggests that there are no live services within the site boundaries.

Remnants of the underground utilities originally servicing the former Tudor Inn are likely to remain in the ground, albeit potentially disconnected. However, it should be appreciated that the above should be used with caution as the source records are now nine years old. Updated service records should be obtained prior to any further intrusive investigation or development.

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 Table 1 below.

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1881 - 1970	The south eastern majority of the site is indicated to be open land, probably pasture, with a building, Cae-Rhys-ddu, in the central area (possibly a farmhouse). The north-western area is tree-lined. The building had been extended by 1919 with outbuildings to the rear. By 1935, the frontage (north-west) of the site had been redeveloped with a probable driveway, and vehicle turning area. A tank is shown in the southern corner, possibly holding a water supply for animals in the field.	The site is located in a rural setting, with the precursor to Cae Rhys Ddu Road running north-east to Cymmle (Cimla) Common. Two wells are shown to the west of the site, with a 'coal pit' 100m to the west (see Figure 2). By 1899/1900, Westernmoor Cottages are shown to the north of the site, and the coal pit to the west is no longer shown. However, a number of old coal pits and levels are shown to the south-east and south. By 1919, an old quarry is shown to the north, adjacent to the Westernmoor Cottages. By 1957 the housing estates to the north had encroached southwards as far as Cae Rhys Ddu Road, and by 1963, the houses on Beacons View to the east had been built.
1971 – present day	The outbuildings of Cae-Rhys-Ddu had been demolished and the building is shown as a 'club'. This building was apparently extended by 1983 and was known as the 'Tudor Inn'.	The area of housing to the north and east underwent marginal changes.

Notes to Table 1:
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 summary, the site appears to have remained undeveloped until the 1970s when the Tudor Inn was constructed. The Tudor Inn was apparently demolished in 2009 (see Section 2.2.2) and the site has remained undeveloped since that date.

2.2.2 Other Sources

Wales Online reports that the Tudor Inn was badly damaged by a fire in January 2009, and subsequently suffered significant vandalism (walesonline, 2009). The news article, dated April 2009, states that the building was due to be demolished later in 2009.

2.2.3 Archaeological Setting

A full archaeological assessment was not included within the brief, but we have not been advised of, or identified, any obvious evidence of any significant archaeological features on the site.

2.3 Previous Investigations and Assessments

With the exception of the ESP investigation of 2013 (see Section 1.1) and a boundary condition report and recent desk study (see below), we are not aware of any previous geotechnical or geo-environmental investigations or assessments at the site.

A copy of a Boundary Condition Report, prepared by 4m Development Services Ltd (4MDS) was provided to ESP for our 2013 assessment, and is presented in Appendix D of this report. The site boundary was investigated by 4MDS in eleven separate sections and the following remedial options were recommended:

- Consideration should be given to treating Boundaries G, H, J and K (4MDS designation for south-western margins) by re-grading the embankment to create a stable slope and stabilising with a geo-grid and landscaping;
- An application of netting to Boundary F (southern margins) to the exposed rock face and/or fill against the vertical face;
- The onsite bedrock has a near-horizontal bedding plane and achieving interface with fractures for soakaway drainage may be difficult. On-site percolation tests are recommended; and
- Some plots may require terracing in gardens and others may require re-orientation to increase clearance to the boundary steep slope.

Integral Geotechnique (Wales) Ltd (IGWL) prepared a desk study assessment for the Client in 2022 (IGWL, 2022). The data sources presented in this report are significantly more recent than those in the previous ESP assessment (from 2013), so these more recent sources have been reviewed and are presented as appendices in this assessment.

2.4 Hydrology

2.4.1 Surface Water Features

The site lies on the upper south-west facing slopes of the River Neath, which flows from north-east to south-west some 1km to the west. The closest surface water features to the site are the Crythan Brook, which flows from east to west some 240m to the south-west of the site, and the Eastland Brook, which flows from east to west some 150m to the north-east. Both these brooks are tributaries of the River Neath.

2.4.2 Surface Water Abstractions

The environmental data report (Appendix C) indicates that there are no surface water abstractions within 250m of the site.

2.4.3 Flooding (Rivers and Seas)

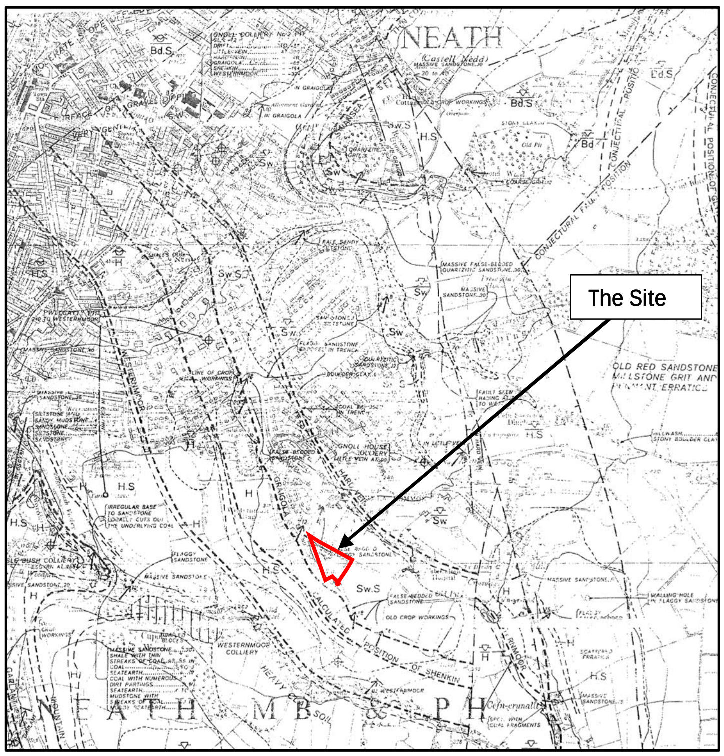
From a review of topographical plans and flooding maps presented in the environmental data report, the site is not indicated to be at risk of flooding by rivers, reservoirs or surface water, and it does not lie within a Flood Alert or Warning Area.

2.5 Geology

2.5.1 Published Geology

The published geological map for the area of the site (1:10,560 scale, Sheet SS 79 NE) indicates the site to be underlain by sandstone bedrock of the Swansea Beds of the Upper Coal Measures. No superficial deposits are shown. An extract of the geological map is presented as Insert 2 below. Reference to the up-to-date mapping available on the website of the British Geological Survey (BGS, 2022) indicates a similar succession.

An outcrop of 'false bedded flaggy sandstone' is indicated on the site, probably representing the sandstone exposure on the south-western boundary. The bedrock in the vicinity is shown to dip to the north-north-east at around 12 to 18° to the horizontal.



Insert 2: Extract from BGS Geological Map Sheet SS79NE, original 1:10,560 scale.
Reproduced with permission (BGS licence number: C15/05 CSL)

The Coal Measures bedrock comprises an interbedded succession of sandstone, siltstone and mudstone, with coal seams and associated seat earths. The conjectural outcrop of the Graigola coal seam is shown to run broadly north-south some 20m to the west (downslope) of the site. Therefore, with a north-north-easterly dip, this seam would be anticipated to underlie the site at shallow depth.

The generalised succession shown on the geological map indicates the Graigola seam to be 5 ft (1.5m) in thickness in the area, and to be underlain by the Swansea Two Feet or Shenkin (a thin seam), and the Westernmoor (2ft or 0.6m thickness) at depths of 45 and 80m beneath the Graigola respectively. These two seams are also anticipated to underlie the site, albeit at greater depth.

2.5.2 Available BGS Borehole Records

Reference to the website of the British Geological Survey (BGS, 2022) indicates no available records of boreholes in the vicinity of the site. The findings of the ESP investigation of 2013 are discussed later in this report.

2.6 Hydrogeology

2.6.1 Aquifer Classification

Reference to the aquifer maps published in the environmental data report (Appendix C) indicates that the Coal Measures bedrock beneath the site 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.

2.6.2 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 bedrock strata. However, localised perched water bodies within the overlying shallow soils cannot be discounted.

2.6.3 Abstractions and Groundwater Vulnerability

The environmental data report (Appendix C) indicates that there are no groundwater abstractions or Source Protection Zones within 500m of the site.

The groundwater vulnerability is shown in the environmental data report to be ‘medium’.

2.6.4 Groundwater Movement

Groundwater movement within the Coal Measures bedrock is likely to be dominated by fracture flow.

2.7 Environmental Setting

2.7.1 Summary of Environmental Data

The site exists in a historically, and current urban, rural margins setting. The environmental data report is presented in Appendix C, and the data therein is summarised in Table 2 overleaf and, where salient, discussed further in Section 2.7.2.

Table 2: Summary of Environmental Data

Feature	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites[2]	None identified.	None recorded within 250m of the site.
Discharge Consents	None recorded.	One recorded within 250m. See Section 2.7.2.
IPPC Authorisations	None recorded	None recorded within 500m of the site.
Pollution Incidents	None recorded.	None recorded within 250m of the site.
Registered Radioactive Substances	None recorded	None recorded within 500m of the site.
Waste Management Sites	None recorded on site. See Section 2.7.2.	None recorded within 500m of the site.
Potentially Infilled Land	None recorded	One recorded within 250m of the site. See Section 2.7.2.
Hazardous Substance Sites	None recorded	None recorded within 500m of the site.
Contemporary Trade Directory Entries	None recorded.	One recorded within 250m of the site. See Section 2.7.2.
Fuel Station Entries	None recorded	None record within 250m of the site.

Notes to Table 2:
1. Full details of features presented in environmental 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.

2.7.2 Further Discussion on Salient Environmental Features

Discharge Consents:
One discharge consent is recorded some 85m to the north-west, for an unspecified discharge to land. The consent expired in 1994.

Waste Management Facilities:
The index of the environmental data report suggests a waste facility on site. However, this appears to be indicative of an available record and no evidence waste management facilities is identified on site.

Potentially Infilled Land:
Potentially infilled ground or a pit is indicated 115m to the south-west of the site.

Contemporary Trade Directory Information:
The closest record is 150m to the north, and comprises inactive waste disposal services (Peter Court), although this appears to be a private address (probable Registered Office). No further trade addresses are recorded within 250m.

2.7.3 On-Site Bulk Liquid Storage

The field reconnaissance visit has provided no evidence of any past or recent above ground or underground bulk liquid (e.g. fuels/oils) storage on site. A tank was shown in the southern corner of the site on historical maps from prior to the 1970s, and the development of Tudor Inn. Given this, the tank may have contained water for animals.

2.7.4 On-Site Bulk Materials and Waste Storage

The field reconnaissance visit indicated no evidence of recent materials or waste storage on the site. The apparent remnants of the former Tudor Inn building are present on the site as an ad-hoc stockpile (see Figure 2, and Plates 3 to 6).

2.8 Preliminary Geotechnical Risk Register

2.8.1 Summary of Potential Geotechnical and Geomorphological Hazards

The potential for various geotechnical and geomorphological hazards at the site is provided in the environmental data report (Appendix C) and detailed further in a stability report obtained by IGWL (Appendix E). The potential hazards, as defined by the British Geological Survey (BGS) and reported in the above reports are listed in Table 3 below, along with any salient further information on the potential hazard identified by ESP in the preparation of this report. Where a potential hazard has been identified, it is discussed further in subsequent sections.

Table 3: Preliminary Geotechnical Risk Register

Ground Stability Hazard	Potential[1]	ESP Comment
Coal Mining	The site is located in an area of past coal mining	See Section 2.8.2
Mining (non-coal)	The site is not located in an area of past mining.	No further information identified to contradict data report.
Shrinking or Swelling Clays	No Hazard	No further information identified to contradict data report.
Landslides/ Slope Instability	Very Low	No further information identified to contradict data report.
Ground Dissolution (Soluble Rocks)	No Hazard	No further information identified to contradict data report.
Compressible Ground	No Hazard	No further information identified to contradict data report.
Collapsible Ground	Very Low	No further information identified to contradict data report.
Running Sand	No Hazard	No further information identified to contradict data report.
Sulphate/Pyritic Ground	Not reported.	See Section 2.8.3
Unexploded Ordnance	Not reported.	See Section 2.8.4

Notes to Table 3:
1. Potential as reported in environmental data report (Appendix C)
2. Salient hazards discussed in following sections.
3. An updated Geotechnical Risk Register, including the results of the intrusive investigation of salient hazards, is presented in Section 8.2.

2.8.2 Past Coal Mining

As discussed in Section 2.5.1, the site is underlain by bedrock of the Upper Coal Measures, which contains several seams of coal. The Graigola seam is shown on geological maps to crop out just to the west of the site (see Insert 2) and is anticipated to underlie the site at shallow depth. This seam is indicated to be 1.5m in thickness in the area, and to be underlain by the Swansea Two Feet or Shenkin (a thin seam), and the Westernmoor (0.6m thick) at depths of 45 and 80m beneath the Graigola respectively.

Reference to the Coal Authority website (CA, 2022) provides the following salient information:

- The outcrop of a coal seam is shown just to the west of the site. Reference to the published geology (Section 2.5.1) suggests that this is the Graigola seam.
- No past surface hazard or surface mining is identified in the vicinity of the site.
- No recorded past shallow coal mining is indicated in the immediate vicinity of the site.
- 'Probable' past shallow coal mining is indicated associated within the outcrop of the Graigola seam to the north of the site.
- No mine entries are shown within the site boundary.
- The site lies immediately to the north-east of a 'Development High Risk Area', apparently associated with the outcrop of the Graigola coal seam.

A CON29 mining report was obtained from the Coal Authority for the site by IGWL as part of the 2022 assessment and this is reproduced in Appendix F of this report. This indicates that, based on the available Coal Authority records, there are 'known or potential coal mining risks' at the site, and:

- The property is in a surface area that could be affected by underground mining in 2 seams of coal at 80m to 280m depth, and last worked in 1903. Any movement in the ground due to coal mining activity associated with these workings should have stopped by now.
- The property is in an area where the Coal Authority believes there is coal at or close to the surface. This coal may have been worked at some time in the past. The potential presence of coal workings at or close to the surface should be considered, particularly prior to any site works or future development activity, as ground movement could still be a risk.
- The property is not in an area where the Coal Authority has received an application for, and is currently considering whether to grant a licence to remove or work coal by underground methods, nor is it in an area where a licence has been granted to remove or otherwise work coal using underground methods. However, reserves of coal exist in the local area which could be worked at some time in the future.
- No notices have been given, under section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence.
- There are no recorded coal mine entries known to the Coal Authority within, or within 20 metres, of the boundary of the property. There may be unrecorded mine entries in the local area that do not appear on Coal Authority records.
- The Coal Authority is not aware of any damage due to geological faults or other lines of weakness that have been affected by coal mining.
- The property is not within the boundary of an opencast site from which coal has been removed by opencast methods, or within 800m of licensed future opencast sites.
- The Coal Authority has not received a damage notice or claim for the subject property, or any property within 50 metres of the enquiry boundary, since 31 October 1994.
- There is no current Stop Notice delaying the start of remedial works or repairs to the property.

- The Coal Authority is not aware 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.
- The Coal Authority has no record of a mine gas emission requiring action.
- The property is not in an area where a notice has been given under section 41 of the Coal Industry Act 1994, cancelling the entitlement to withdraw support.

The stability report (Appendix D) identifies former ‘opencast’ sites some 20m to the north-west of the site (Westernmoor Cottages), and 150m to the south-east (Cae Rhys Ddu). Both these sites reportedly worked sandstone and likely to be former quarries rather than traditional opencast sites. The old quarry on the southern boundary of the site is also identified.

The stability report references workings beneath the site in the Esgyrn (or Erskine, Hughes or Garlant) seam which ceased in 1903, the Rotten (or Bodwr) seam which ceased in 1859, the Western Moor and Western Moor Two Feet seam which ceased in 1888. The Garlant, Esgyrn and Bodwr seams all lie well beneath Westernmoor in the succession, i.e. in excess of 50m depth beneath the site.

Although there are no records of past mine workings at shallow depth beneath the site, the Graigola seam (which crops out to the west and is anticipated to underlie the site at shallow depth) is indicated to be 1.5m in thickness in the area. Given this reported thickness, the recorded position of the outcrop just to the west of the site, the identified presence of an old ‘coal pit’ close to the outcrop around 100m to the south-west of the site (see Figure 2), and the fact that the seam was mined extensively across the Swansea and Neath area (Arup, 1994), we consider it to be almost inconceivable that the seam has not been worked beneath the site. The seam outcrop to the west would have allowed relatively easy access to the coal via adits (tunnels into the bedrock to work the coal – as shown on historical maps).

Further mine shafts are indicated north-east of the outcrop, some 450m east of the site – these are likely to have intercepted the Graigola seam at shallow depth, and probably accessed workings within the seam. Such potential workings are indicated by the Coal Authority within the Graigola seam to the north of the site.

Given the above, we consider that the risk from shallow mining is potentially **High.**

2.8.3 Pyritic Ground

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

The weathered Coal Measures bedrock soils underlying the site are not anticipated to contain elevated levels of pyrite, which could oxidise to sulphates. Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be **Low.**

2.8.4 Unexploded Ordnance

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

Reference to the Regional UXO risk maps available on-line (Zetica, 2023) suggests that the site is located within a **Low** risk region with regards to the risk from buried unexploded ordnance. However, it should be appreciated that although the area of the site is indicated as generally of low risk, an increased could be applicable due to site-specific features, e.g. war-time activities.

We recommend that, as a minimum, prior to any further investigation or development works, a Preliminary Desk Study assessment of UXO risk is obtained from a specialist consultant.

2.9 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures.

The environmental data report (Appendix C) indicates that the site lies in a radon affected area as defined by the Health Protection Agency, with between 3 and 5% of properties above the action level. Reference to current radon protection guidance available on the BGS website (BGS, 2023) indicates that the site is located within an area where less than 1% of properties are above the action level, but just south of an area where between 10 and 30% of properties are above the action level. 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.

Given the currently available information, the risk from radon is considered **Moderate,** and we recommend, as a minimum, basic radon protection be provided to the new development.

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 desk study review has identified no evidence of any prior development or former contaminative use on the site. Therefore, we have not established the presence of any potential sources of contamination. Notwithstanding this, on any site, the presence of pockets of Made Ground, which could contain elevated levels of soil contaminants cannot be fully discounted. In particular, on former agricultural land (as this was prior to development as the pub), former hollows may have been infilled in the past with unknown materials, and can be a source of contamination. The presence of ad-hoc fires are also evident on the site surface – the burning of organic materials can leave remnant polyaromatic hydrocarbon (PAH) compounds in the shallow soils.

Occasional fragments of asbestos cement and suspected asbestos insulation were observed within the demolition stockpile materials (see Plate 7). Given its age, Tudor Inn is likely to have contained asbestos materials within its structure (e.g. lagging, insultation, guttering etc), and these may not have been removed prior to the demolition of the fire-damaged building. Therefore, we cannot discount that further fragments of asbestos containing materials are present within the stockpile. Smaller fragments of asbestos cement sheet were also observed within the shallow soils just to the south-east of the stockpile.

3.1.3 Potential Contaminants Present

To date, the only contaminant identified as being present on site is asbestos, within the demolition stockpile. However, if Made Ground is present on site, the presence of metals, sulphates, cyanide, polyaromatic hydrocarbon compounds and phenols cannot be discounted, along with asbestos containing materials within the shallow soils (in addition to the stockpile).

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 2.9.

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 2.9.

The site is not located within 250m of an existing or former recorded landfill, nor are there any recorded instances of land filling in the vicinity. From the desk study information, there is no evidence of any potential on-site or nearby off-site sources of hazardous ground gas at the site.

However, the site is potentially underlain at shallow depth by abandoned mine workings within the Graigola coal seam (see Section 2.8.2). Such workings could prove a source of hazardous ground gas.

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas source (abandoned mine workings) would generally be classified as of very low gas generation potential, but a **Moderate to High** risk to development.

3.1.5 Potential Receptors

As discussed in Section 1.1, the proposed site development will comprise residential properties with private gardens, landscaping and vehicle parking areas. The site is located 150m from the nearest surface water course, and above a Secondary A Aquifer with little superficial cover.

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

- Future residents, the critical receptors being young children playing in private garden areas.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The general groundwater quality within the Coal Measures strata beneath the site.

3.1.6 Potential Migration Pathways

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 garden and landscaping areas.
- Ingestion of edible plants and dust associated with such plants.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas from on-site sources (mine workings).
- Potential risk from toxic ground gas from on-site sources (mine workings).
- Chronic (long term) exposure to unacceptable levels of radon.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the demolition rubble stockpile.
- 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 from on-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the bedrock.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas from on-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 4 in Section 3.2.2 overleaf.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 4: 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 (residents)	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	Unlikely[2]	Very Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary A Aquifer	Low likelihood[2]	Moderate/Low Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
	Leaching of soil contaminants	Impact on River Neath	Mild – site lies some distance from river	Unlikely[2]	Very Low Risk	
Asbestos in existing stockpile	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	High Likelihood[3]	High Risk	Asbestos survey of stockpiles
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	High Likelihood[3]	High Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Unlikely[4]	Very Low Risk	Sampling of soils to confirm levels of sulphate, pH.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	High likelihood[4]	Very High Risk	Install and monitor gas wells into coal/mine workings.
	Damage through explosion.	Building/Property	Severe – acute risk.		Very High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Very High Risk	
Radon gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	High Likelihood[7]	High Risk	See Section 7.3.2

Notes to Table 4:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. The presence of Made Ground or contamination has not yet been confirmed on site. See Section 3.1.2.
3. Asbestos has been observed within the stockpiled materials, and fragments of asbestos cement just to the south-east of the stockpile. See Sections 3.1.1 and 3.1.2.
4. The weathered Coal Measures bedrock is unlikely to contain sulphates/pyrite. See Section 2.8.3.
5. The potential shallow mine workings would be a potential source of hazardous ground gas. See Section 3.1.4.
6. Radon risk identified in environmental data report. See Section 2.9.
7. The above risk evaluation is updated following the intrusive investigation and testing in Table Table 6 in Section 6.2.

4 Exploratory Investigation

4.1 Background

The following sections discuss the scope of investigation works undertaken in 2013 across the site by Earth Science Partnership. It should be appreciated that these works were undertaken in accordance with the British Standards and UK guidance applicable at that time.

4.2 Investigation Points

4.2.1 Introduction

The intrusive investigation was undertaken in two phases in 2013 in accordance with BS5930:2010 and BS10175:2011, and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised an initial phase of trial pitting and soakaway infiltration testing, followed by the construction of rotary drillholes to investigate the potential mining hazard.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2010, BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2004, and BS EN ISO 14689:2003, along with published weathering schemes. Descriptions and depths of the strata encountered are presented on the borehole and trial pit records in Appendix G and I, with the results of the in-situ testing presented in Appendix H. The investigation point positions are shown on Figure 3.

The ground levels and coordinates indicated on the investigation point records are for the centre of the site.

4.2.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2011, taking into account the additional potential for geotechnical hazards to be present.

As no specific potential contaminant sources or geotechnical hazards were identified within the shallow soils in the desk study (see Section 3.1.2), the investigation points were spread across the site to obtain a general overview of the ground conditions present. The investigation point locations were positioned to maximise the information that could be obtained, allowing for the constraints imposed by the physical features on site including the presence of the stockpile of demolition rubble. Notwithstanding the above constraints, we consider that the investigation undertaken has been sufficient to identify the key ground issues at the site.

4.2.3 Trial Pits

Ten trial pits (TP1 to TP10) were excavated across the site on 21st February 2013 using a wheeled, backacting hydraulic excavator. The trial pits were excavated to depths of between 0.2 and 3.2m, and were commonly shallow (less than 1m) due to the presence of very shallow bedrock.

Where required, the tarmacadam surface was broken out prior to the excavation of the pits using a hydraulic breaker. Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records. The trial pit records are presented as Appendix G.

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

4.2.4 Soakaway Infiltration Testing

Soakaway infiltration tests were undertaken in general accordance with BRE Digest 365 (2007) on 21st February 2013 in three selected trial pits across the site (TP1, TP5 and TP7). The results of the infiltration testing, and the calculated infiltration rates, are presented in Appendix H. The positions of the test pits are shown on Figure 2.

At each position, the test pit was initially commenced by conventional excavation. However, shallow bedrock was encountered at depths of less than 0.5m, so the hydraulic breaker was used to extend the depth of the test pit. 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 the water level only dropped marginally during the available test period (e.g. not as far as the 75% full level – TP7), 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 two fills) in Test Pit TP5, however, due to the low infiltration rate, insufficient time was available to repeat the test in Test Pit TP1. Only minimal infiltration was recorded in TP7.

4.2.5 Rotary Open-hole Drillholes

Three 100mm diameter rotary percussive open-hole drillholes (RO1 to RO3) were constructed to depths of between 21 and 30m, between 13th and 15th March 2013. The borehole records are presented as Appendix I, and their positions are shown on Figure 3.

At the commencement of each borehole, a service inspection pit excavated by hand to a depth of 1.2m.

Given that the objective of the drillholes was to intercept coal seams/workings, they were constructed under license to the Coal Authority (Permit ref. 7641). 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.

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. 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 arisings.

4.3 Evidence of Site Hazards Found During Site Works

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

4.3.1 Site Stability

Shallow bedrock was recorded across the majority of the site. In excess of 3m of Made Ground was identified in the south-western margins (TP9), which suggests an area of filling. Such fill materials could be unstable if loaded. An assessment of the boundary conditions was undertaken by others (see Section 2.3).

4.3.2 Site Evidence of Contamination

No direct visual/olfactory evidence of contamination was identified in the exploratory holes. However, Made Ground was present in the north-west of the site beneath the surface tarmacadam, and as an area of apparent filling in the south-western margins (TP9).

Suspected asbestos containing materials were identified in the demolition arisings. As a result, the area around the arisings stockpile was avoided and no investigative work was undertaken within or beneath the footprint of the stockpile due to the elevated risk to site operatives from asbestos.

4.4 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.

Selected samples of the shallow soils were analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). The results are presented in Appendix J.

4.5 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil. The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Section 5.4.3).

The Preliminary Risk Assessment (Section 3.1) did not identify any particular contaminants of concern within the shallow soils. However, given the identified presence of Made Ground in the exploratory holes and the sensitive nature of the proposed development (residential), in order to allow an assessment of the potential chronic risks posed to human health, a total of five selected samples of shallow soils have been analysed for contaminants typically found on brownfield sites in the UK.

This includes one sample from the south of the site (TP3), where a tank was formerly shown on historical maps.

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

- Arsenic, cadmium, total chromium, chromium VI, lead, mercury, nickel, selenium.
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value;

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

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 thin veneer of Made Ground or Topsoil, overlying weathered Coal Measures bedrock at very shallow depth (less than 1m) On the south-western margins, a greater thickness of Made Ground (in excess of 3m) was identified. These strata are discussed in more detail in the following sections. The geological succession identified in the exploratory holes is presented on a Conceptual Ground Model in Figure 4.

Made Ground: encountered beneath the hard surfaced areas around the former Tudor Inn building (TP7, TP8 and TP10) as a tarmacadam surface underlain by a probable gravel sub-base, with occasional fragments of tile, to a depth of 0.15 to 0.3m.

On the south-western boundary, TP9 identified a substantially greater thickness of Made Ground to depths in excess of 3.2m (the base of the pit), comprising black/brown, slightly clayey, sandy gravel with many fragments of brick, concrete, plastic, tiles, ceramics, glass, metal, rope and carpet. The pit sides were very unstable in these soils. This pit lies on the margins of the site, where the ground falls away to the south-west, and we consider that the Made Ground is likely to represent fill materials end-tipped over the previous site margins, possibly to create additional space on site. A chocolate bar wrapper found at around 1.1m showed a 'best before' date of June 1990, suggesting that the date of the tipping is likely to be around that time.

Topsoil: encountered at the surface in the south-east of the site (away from the Tudor Inn hard surfacing), and comprising the comprises dark brown, slightly sandy clay of soft consistency, with common rootlets.

Glacial Diamicton: not encountered in the trial pits, but possibly present in the form of clay and boulders in the area of Borehole RO1, in the north-western margins of the site.

Weathered Coal Measures Bedrock: encountered identified at a very shallow depth, less than 0.5m below the site surface in all the trial pits across the main part of the site (except TP9 on the south-western margins), as a weak to medium strong, light brown grey, very thinly to thinly laminated, highly to moderately weathered, sandstone, which was recovered as a slightly sandy, angular, medium coarse gravel with many cobble and boulder sized fragments of sandstone. The trial pits commonly failed to penetrate more than 100 or 150mm depth into this bedrock without the use of a hydraulic breaker.

The rotary boreholes indicated the initial weathered sandstone to be underlain by a coal seam and then mudstone, with a band of mudstone also above the coal in Borehole RO1. The coal seam was at depths of between 4.0m (in RO1 in the north-western margins) and 12.5m (in RO3, in the eastern margins). The seam was around 2.8m in thickness in Borehole RO1, 1.6m in Borehole RO2, and 1.0m in Borehole RO3, and is considered to be the Graigola coal which crops out to the west of the site.

5.2 Conceptual Ground Model - Hydrogeology

No shallow groundwater was recorded in the trial pits. The investigation did not identify any groundwater to a depth of 30m within the rotary drillholes. However, the drillholes were completed with air mist flush which could have masked groundwater strikes.

5.3 Site Instability

5.3.1 Global Site Stability

No evidence was identified of potential landslides or unstable ground in the Preliminary Geotechnical Risk Register (Section 2.8.1). The only evidence of possible instability was recorded in the south-western margins where the original site surface appears to have been filled (in TP9) – this area is not clearly visible at present due to the presence of dense vegetation.

5.3.2 Excavation Stability

No side wall instability was experienced during the excavation of the majority of the (very shallow) trial pits. However, on the south-western boundary, excavation within TP9 was halted due to collapse of the side walls within the probable end-tipped fill materials.

5.3.3 Mining Hazard

As discussed in Section 5.1, the investigation has identified the Graigola coal seam to be present at depths of between 4.0 and 12.5m across the site. See Section 8.2.2 for further discussion.

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 conventional residential properties with private gardens. Therefore, the GAC appropriate for the residential land use with plant uptake have been adopted in this assessment.

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 0.8 to 5.8%. 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 three samples of Made Ground, one sample of Topsoil (TP1) and one sample of the weathered bedrock (TP5). At this stage, all samples have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 5.4.4.

The results of the Generic Quantitative Risk Assessment for the proposed development are presented in Table 5. below. It should be appreciated that if the development were to change, the following assessment should be reviewed and, if necessary, updated.

Table 5: Generic Assessment of Human Health Risks

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	1.9 - 9.6 mg/kg	37mg/kg	C4SL[2]	None of 5
Cadmium	<0.1 – 2.3 mg/kg	26mg/kg	C4SL[2]	None of 5
Chromium (total)[7]	7.5 – 440 mg/kg	910mg/kg	S4UL[4]	None of 5
Chromium (hexavalent)	<1.0 mg/kg	21mg/kg	C4SL[2]	None of 5
Lead	1.7 – 35 mg/kg	200mg/kg	C4SL[2]	None of 5
Mercury[8]	<0.05 – 0.11 mg/kg	40mg/kg	S4UL[4]	None of 5
Nickel	1.5 – 20 mg/kg	130mg/kg	S4UL[4]	None of 5
Selenium	<0.5 – 12 mg/kg	250mg/kg	S4UL[4]	None of 5
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.1 – 0.6 mg/kg	210mg/kg	S4UL[4,9]	None of 5
Acenaphthylene	<0.1 – 1.1 mg/kg	170mg/kg	S4UL[4,9]	None of 5
Anthracene	<0.1 – 0.8 mg/kg	2,400mg/kg	S4UL[4,9]	None of 5
Benzo(a)anthracene	<0.1 – 0.7 mg/kg	7.2mg/kg	S4UL[4,9]	None of 5
Benzo(a)pyrene	<0.1 - 1.1 mg/kg	5mg/kg	C4SL[2,9]	None of 5
Benzo(b)fluoranthene	<0.1 – 0.7 mg/kg	2.6mg/kg	S4UL[4,9]	None of 5
Benzo(ghi)perylene	<0.1 - 1.1 mg/kg	320mg/kg	S4UL[4,9]	None of 5
Benzo(k)fluoranthene	<0.1 – 0.5 mg/kg	77mg/kg	S4UL[4,9]	None of 5
Chrysene	<0.1 – 2.2 mg/kg	15mg/kg	S4UL[4,9]	None of 5
Dibenzo(a,h)anthracene	<0.1 – 0.4 mg/kg	0.24mg/kg	S4UL[4,9]	1 of 5
Fluoranthene	<0.1 – 2.6 mg/kg	280mg/kg	S4UL[4,9]	None of 5
Fluorene	<0.1 – 1.6 mg/kg	170mg/kg	S4UL[4,9]	None of 5
Indeno(123-cd)pyrene	<0.1 – 0.7 mg/kg	27mg/kg	S4UL[4,9]	None of 5
Naphthalene	<0.1 – 0.3 mg/kg	2.3mg/kg	S4UL[4,9]	None of 5
Phenanthrene	<0.1 – 2.8 mg/kg	95mg/kg	S4UL[4,9]	None of 5
Pyrene	<0.1 – 2.3 mg/kg	620mg/kg	S4UL[4,9]	None of 5
Other Organic Compounds				
Phenol	<0.3 – 0.6 mg/kg	280mg/kg	S4UL[4,9]	None of 5

Notes to Table 5:

1. Assessment for residential land use with home-grown produce uptake.
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. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.

7. GAC for inorganic mercury adopted.
8. GAC for organic compounds based on 1% soil organic content.
9. Exceedances highlighted in red and bold.
10. Laboratory results presented in Appendix K.

From Table 5, it is clear that all the determinands analysed were below their respective GAC across most of the site. The only exceedance was recorded in the Topsoil of TP1 where the PAH compound dibenzo[ah]anthracene exceeded the GAC.

5.4.4 Asbestos

No evidence of asbestos was identified in the soil samples analysed.

5.5 Sulphate Attack

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

5.5.1 Classification of Site

Due to the presence of shallow Made Ground across part of the site, we consider that it should be considered as ‘brownfield’ in terms of concrete classification.

5.5.2 Groundwater Setting

No groundwater was encountered in the trial pits to a depth of 3.2m, and in the deeper rotary drillholes. However, no long term monitoring (in excess of 24 hours) of groundwater levels has been undertaken. Therefore, in accordance with the BRE guidelines, we recommend that groundwater be considered as ‘mobile’ in terms of foundation concrete assessment.

5.5.3 Sulphate Levels

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the shallow soils to be between less than 0.01 and 0.04mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between less than 0.01 and 0.19%. pH values varied between 5.9 and 7.5, indicating slightly acidic to near neutral soil conditions to exist.

5.5.4 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:	30mg/l; and
pH value:	6.0.

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

A thin veneer of Made Ground is present beneath the tarmacadam across the northern part of the site (the former hard surfacing around Tudor Inn), but levels of contaminants were found to be low. A greater thickness of Made Ground was recorded on the south-western margins in TP9, however, the levels of contaminants were identified as being low within this shallow Made Ground.

The only elevated contaminant level identified was the PAH compound dibenzo[ah]anthracene within the Topsoil in the south-east of the site (TP1). This elevated level may be the result of past burning of organic materials (e.g. surface fires – see Section 3.1.2).

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 4, Section 3.2.2) have been updated and revised in Table 6 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 6: 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 (residents)	Medium – potential for chronic levels.	Unlikely[2]	Low Risk	See Section 7.1.2
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Unlikely[2]	Very Low Risk	See Section 7.1.4
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary A Aquifer	Unlikely[2]	Low Risk	See Section 7.2
	Leaching of soil contaminants	Impact on River Neath	Mild – site lies some distance from river	Unlikely[2]	Very Low Risk	
Asbestos in existing stockpile	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	High Likelihood[5]	High Risk	See Section 7.1.1
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	High Likelihood[5]	High Risk	
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Unlikely[4]	Very Low Risk	See Section 7.4.2
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	High likelihood[4]	Very High Risk	See Section 7.3.1
	Damage through explosion.	Building/Property	Severe – acute risk.		Very High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Very High Risk	
Radon gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	High Likelihood[7]	High Risk	Minimum basic radon protection required.

Notes to Table 6:

1. This table updates Table 4 in Section 3.2.2 using results of the investigation. Methodology and details of risk consequence, probability and category presented in Appendix A.
2. The only exceedance was by dibenzo[ah]anthracene in the Topsoil in the south-east of the site - see Section 5.4.3.
3. Levels of soil contaminants were low – see Section 5.4.3.
4. Low levels of sulphates were recorded - see Section 5.5.4.
5. Asbestos materials suspected in demolition rubble stockpile, no asbestos identified in shallow soils, but asbestos materials observed on site surface – see Section 5.4.4.
6. Radon risk identified in environmental data report – see Section 2.9.
7. Possible coal workings could create source of hazardous ground gas – see Section 3.1.4.

7 Outline Remedial Strategy for Contamination Risks

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date. 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 during the testing of the shallow soils beneath the site. However, suspected asbestos materials have been observed within the stockpile of demolition rubble and on the surface just to the east of stockpile – the surface asbestos materials may have been created by deliberate damage to materials originating in the stockpile since our 2013 investigation.

The stockpile will need to be removed for development and should be sampled and analysed for asbestos prior to its removal – this sampling should extend to the site surface around the stockpile. On removal, appropriate precautions should be taken to ensure that any asbestos materials present are not spread across the remainder of the site surface (e.g. by spillage). Further testing of any shallow surface soils beneath the stockpile will be required to ensure that no remnant asbestos materials remain following removal.

If any further 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 residential properties, the identified levels of soil contamination at the site are generally not considered to pose a risk to future site users. Therefore, no specific site-wide remedial measures are considered necessary for the development.

However, an unacceptably elevated level of the PAH compound dibenzo[ah]anthracene was identified in the south-east of the site (TP1), and is suspected to be a remnant from past surface burning of organic materials. The elevated levels are unlikely to prove a risk beneath hard surfaces such as dwelling floor slabs or tarmacadam hardstanding, but could pose a risk to residents in garden and landscaping areas. We recommend further sampling and testing of surface soils in garden and landscaping areas over this part of the site to define the extent of the elevated levels. The most likely optimum remedial solution would be the removal of the shallow soils containing the elevated levels of contaminants (generally 200 to 300mm thickness).

Where evidence of past burning is noted on the site surface elsewhere on site (e.g. to the south-east of the stockpile), a similar approach of localised sampling and testing is recommended where these areas are located in proposed gardens/landscaping.

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 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.

A copy of this report and these recommendations should be included in the Health and Safety File for the development and provided to all future ground workers, including utility companies so that they may undertake their own assessment of risks to their operatives.

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

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

- No past contaminative use has been identified at the site.
- Only limited Made Ground has been generally identified on the site.
- The levels of soil contaminants are generally low, well below the GAC adopted.
- The proposed development comprises a conventional residential estate which will include areas of car parking which are anticipated to be hard surfaced – surface drainage from these areas could contain leached oils and fuels from vehicle spills and leaks.
- Soakaways are being considered for the development.
- The site is underlain by only limited soils above weathered bedrock present at very shallow depth (less than 0.5m).
- The bedrock beneath the site is classified as a Secondary A aquifer. However, coal seams within the bedrock have been worked in the past, possibly at shallow depth (within 10 to 20m of the surface). Groundwater is anticipated within the weathered bedrock at depths, possibly below 30m depth.

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

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

The main potential source of hazardous ground gas at the site is the potential abandoned shallow mine workings within the Graigola coal seam (see Section 3.1.4). No gas monitoring has been undertaken at the site to date.

Wilson et al (2021) indicate that the sole use of the standard assessment methodology for assessing risks from hazardous gas (designed for use for shallow gas sources and based on BS8285:2015) should be used with extreme caution when assessing gas risks from abandoned mine workings. It may, however, be used as one of multiple lines of evidence. Wilson et al (2021) provide a decision tool based on this multiple lines of evidence approach.

With regards to this multiple lines of evidence approach to mine gas risk assessment, the following salient points have been established from the desk study and investigation undertaken at the site:

- The site is not within an area of past or probable shallow workings (on the Coal Authority website);
- There are no recorded mine entries within the site boundary;
- There is no evidence of past gassing within shallow workings beneath the site;
- There are no recorded faults or other pathways for gas migration to shallow workings from deeper workings;
- The bedrock is present at very shallow depth beneath the site and so no low permeability strata, in terms of gas risk, are present;
- Abandoned coal workings have not yet been identified within 30m of the site surface, but are suspected within the Graigola seam between 10 and 20m depth beneath the site; and
- No evidence of shallow groundwater, which could lead to flooding of workings has been identified.

Based on the above, and the decision tool published by Wilson et al (2021), we consider that the site potentially lies within a **High Risk** zone in terms of mine gas and a detailed mine gas risk assessment is required to identify the requirement for risk mitigation measures – this would require further investigation to determine if shallow mine workings are likely to be present beneath the site. It is noted that Wilson et al (2021) advise that private housing with gardens may require 'specific care' within high risk zones.

7.3.2 Risk to the Development – Radon

As discussed in Section 2.9, the Preliminary Risk Assessment has indicated that, as a minimum, basic radon protection measures are required.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

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

7.4.2 Sulphate Attack on Buried Concrete

From Section 5.5.4, the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	30mg/l;
pH value:	6.0.

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.

The stockpile of demolition materials present on site would be initially classified as waste and cannot be managed under the DoWCoP protocols. If it can be demonstrated (by further testing and assessment) that the materials are compliant with the WRAP protocols, they may be de-classified as waste. Exemptions from the waste legislation may also be applicable. In order for the stockpile materials to be re-used in development, any asbestos materials present must be removed.

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 2.11 a preliminary ordnance assessment should be undertaken prior to any further investigation or development to identify the potential risk to site operatives from unexploded ordnance.

8.1.2 Invasive Plants

Japanese Knotweed was previously identified on the south-western margins of the site, an area which is now heavily overgrown. Japanese Knotweed is an invasive plant which would need to be eradicated from the development site. It has extremely powerful growth potential and has been recorded to penetrate and subsequently destroy concrete and tarmacadam surfaces and damage foundations. Therefore, if it were not treated sufficiently it could have a significant deleterious impact on the development.

There are a number of treatment options available for the eradication of Japanese Knotweed, including its excavation and treatment by herbicides (which may take several growing seasons). Further information is presented in publications by the former Environment Agency (2001) and Welsh Government (2011), or further advice can be provided by this office. Any treatment or removal should be undertaken by specialist, qualified contractors, and it should be appreciated that it is an offence to allow the spread of these plants (e.g. on excavator tracks).

8.1.3 Existing Foundations and Services

The north-western part of the site was previously been developed as the Tudor Inn, and old foundations from this structure are anticipated to remain in the ground. The proposed apartment block is shown in this area and these sub-structures, and any others identified during development, should be grubbed up within the zone of influence of the development as part of the site preparation works.

There are no known live services present within the vicinity of the site. However, up to date service records should be obtained prior to further investigation or development.

A network of land drains is likely to be present and may provide a seepage path into excavations. The 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

We have not been advised that the development requires any significant earthworks. Any proposed changes to the topography should reviewed by a geotechnical engineer.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

The desk study (Section 2) identified the following potential geotechnical hazards at the site:

- Coal mining; and
- Unexploded Ordnance (potential).

The potential Unexploded Ordnance hazard is discussed in Section 8.1.1. The investigation has also identified two further potential hazards:

- Very shallow bedrock; and
- Instability on the south-western margins.

These potential hazards are discussed in the following sections.

8.2.2 Coal Mining Hazard – Shallow Mine Workings

The investigation identified the presence of the probable Graigola coal seam at depths of between 4.0 and 8.8m depth on the south-western margins, and at a depth of 12.5m beneath the north-eastern area. This suggests a dip to the north-east, as indicated on the geological mapping. The seam was recorded as solid coal in all three boreholes, and of between 1.0 and 2.8m thickness, the latter thickness being greater than indicated as typical for the area.

As discussed in Section 2.8.2, the Graigola seam was mined extensively across the Swansea and Neath area and, given its proven thickness beneath the site, and the apparent ease of access from mine entries along the outcrop, we consider it to be almost inconceivable that the seam was not worked beneath the site. Therefore, the coal encountered within the three drillholes constructed to date is likely to represent solid pillars of coal left to support the roof of adjacent mine workings.

The workings, if present, would be present at depths of between 4.0 and 8.8m beneath the south-western margins of the site, and 12.5m beneath the north-eastern area (see Figure 4). The seam/workings are overlain by an apparently competent sandstone roof rock, which could have supported the ground above any voids since the workings were completed. However, the competency of this sandstone is not known and evidence from the trial pits and exposures suggests that near the surface, the stratum is highly fractured. Therefore, we cannot discount that, at some unknown time in the future, the sandstone roof rock could collapse and result in subsidence features on the site surface. Any such collapses could undermine foundations and other infrastructure of any development on site. Given this, we consider that the subsidence risk at the site is **High**.

At present the three rotary boreholes completed have identified a possible hazard, but are not sufficient to define the extent of the hazard to any degree of certainty. We consider that any workings present beneath the proposed apartment block and dwellings to the south-west of the access road are likely to require stabilisation by drilling and grouting. The seam is at greater depth, with a greater rock cover beneath the north-east of the site. Using the well established 'rule of thumb' whereby a bedrock thickness above the workings of ten times the working height being sufficient to mitigate risks, where the sandstone cover is 12.1m (as identified in Borehole RO3), this is likely to be sufficient to mitigate risks above workings up to 1.2m in height – the seam in RO3 was recorded as 10m in thickness. Therefore, the risks to the dwellings to the north of the access road in the east of the site may be lower. However, if the workings were in excess of 1.2m height in this area, unacceptable subsidence risks may be present. Further investigation would be required to further define the risk in this area (see below).

As the seam was identified at only 4.0m depth below the surface in the north-west of the site, any workings beneath this area would also pose an unacceptable subsidence risk to the new access road and vehicle parking areas and would also need to be stabilised to mitigate the risk of a subsidence feature. Further east, the workings are likely to be 10 to 12m depth below the site surface and, hence, the subsidence risk is likely to be reduced, but still potentially significant. The use of geo-grids within the road construction, rather than stabilising the workings, may be sufficient to mitigate the possible subsidence risks in this area.

With the limited information available at this stage, it is difficult to assess the length of the road which could require stabilisation by drilling and grouting. To clarify this, we recommend that further rotary drilling be undertaken across the site to provide additional information on the depth and thickness of the coal seam and the presence and height of any workings – at this stage we recommend a further eight rotary boreholes, taken to maximum depths of around 15m (shallower borehole depths will be appropriate in the south-western and north-western margins, where the seam is shallower). Gas wells should also be installed and monitored within these drillholes to allow a detailed gas risk assessment (see Section 7.3.1).

8.2.3 Coal Mining Hazard – Mine Entries

No mine entries are recorded in the immediate vicinity of the site. However, it should be appreciated that in any area of past mining activity, particularly where the seam is present at as shallow a depth as identified beneath this site, the possibility of the existence of unrecorded mine entries cannot be discounted. The hard sandstone band overlying the coal seam may have encouraged any entries to be adits located on the lower-lying ground outside the western site boundary rather than as shafts from the site surface.

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.

8.2.4 Very Shallow Bedrock

Very shallow sandstone bedrock has been identified across the majority of the site at depths of between 0.1 and 0.35m depth. Although weathered near the surface, this sandstone was hard to excavate and the wheeled backacting excavator used in the investigation (JCB 3CX) generally failed to penetrate more than 200mm depth into the bedrock.

Given this, any trenches required for the development (e.g. for drainage, other services, foundations etc) are likely to require either the use of hydraulic breakers or large capacity excavators. Narrow trenches may be difficult to excavate in the shallow bedrock without the use of hydraulic breakers due to the potential for overbreak (over-widening of trenches).

We recommend that particular attention is paid to the design of drainage falls so that the depth of excavation into the bedrock is minimised.

8.2.5 Site Stability – Filled South-western Margins

The south-western margins of the site appear to have been filled by loose end-tipped materials, as identified in TP9, which are prone to instability. The extent of the filled ground is not clear as the area is currently completely overgrown with dense vegetation, but it may comprise the wider area extending out from the remainder of the south-western boundary.

From Figure 1, this area appears to lie to the south-west of the garden area to the rear of Plots 11 and 12, so we do not anticipate that it will impact on the proposed development. However, we recommend further investigation by trial pitting in the area (and particularly to the rear of Plots 11 and 12) to establish the lateral extent and depth of the fill materials and, hence, the risk to the development.

8.2.6 Site Stability -Former Quarry

A former quarry forms part of the southern boundary, and is believed to be a small, historical sandstone quarry. As discussed in Section 2.3, 4M Development Services (4MDS) undertook an inspection of the quarry face and recommended netting or and/or placement of fill against the rock exposures to maintain stability. However, at present, the quarry face is inaccessible due to dense vegetation, so a full assessment of the stability of the face cannot be made.

This quarry face lies to the rear of Plots 7 and 8 and its stability could impact on the rear garden areas of these dwellings. We recommend that the vegetation be cleared to provide an access to the quarry face so that a full geotechnical inspection can be made of the exposure, and suitable support measures (if required) designed. At this stage, from the available information, we can make the following preliminary comments:

- The available information suggests that the bedding planes of the bedrock are dipping into the face at an angle of 12 to 18°. Hence, large-scale planar or wedge failures are considered unlikely.
- The near-surface bedrock is fractured so toppling failures or unravelling of the rock slope could occur.
- No mudstone bands have been identified at shallow depth, therefore wide-scale bearing capacity failure, where the softer mudstone bands have been eroded, are unlikely.
- Bedrock excavated as part of the development works (e.g. for soakaways, foundations or drainage) could be used to construct dentition or other rock support measures.
- Soakaways constructed above quarry face could have a detrimental impact on its stability.

A suitable stand-off distance will be required between development structures and the top of the rock face – this would be determined after the rock face inspection.

8.3 Foundation Design and Construction

We understand that the site is being considered for potential development for residential purposes and the comments and recommendations in this report assume that the development will involve the construction of typical two-storey structures of conventional load-bearing brickwork construction. The following section assumes that any abandoned mine workings beneath the houses are stabilised by drilling and grouting, as discussed in Section 8.2.2, so that the risks from subsidence are very low.

8.3.1 Spread Foundations

On the basis of the available investigation information, we consider that mass concrete strip foundations could be used at the site constructed within the weathered sandstone bedrock. We recommend that foundations are constructed at a minimum depth of 0.5m in the weathered bedrock. At this depth a presumed bearing value of 200kPa should limit total and differential settlements to less than 25mm. As discussed in Section 8.2.4, the wheeled excavator used for the site works had difficulty excavating to more than 200mm in the bedrock, so such foundation trenches may be difficult to excavate.

The proposed founding stratum is coarse-grained in composition and, therefore, should not be affected by seasonal changes in moisture content.

For all spread foundation options, the formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. 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. We recommend that a blinding layer of concrete be placed on the formation after excavation and inspection in order to protect the formation against softening and disturbance.

As discussed in Section 8.2.3, 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.

8.3.2 Raft Foundations

Given the very shallow bedrock and potential difficulty in excavating foundation trenches, raft foundations founded on the bedrock may prove a more economic foundation solution by minimising excavation depths in the rock. We consider that a subgrade reaction modulus based on the guidance published by Chandler and Neal (1988) of the order of 54 MN/m^3 can be adopted for preliminary design purposes.

The formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. 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. We recommend that a blinding layer of concrete be placed on the formation after excavation and inspection in order to protect the formation against softening and disturbance.

8.4 Floor Slab Foundations

The use of cast in-situ ground bearing floor slabs is considered suitable for the development. Once the Topsoil has been removed, the underlying ground should be compacted for a depth of at least 300mm below slab formation level. The formation should be inspected for any soft or loose spots which, if found, should be excavated and replaced with compacted, suitable, granular fill. Provided this treatment is completed, a subgrade reaction modulus based on the guidance published by Chandler and Neal (1988) for coarse-grained soils of the order of 54 MN/m^3 can be adopted for preliminary design purposes.

As discussed in Section 7.3.1, a potential hazardous gas risk is present at the site, from shallow mine workings. If the gas risk assessment indicates that gas mitigation measures are required, they would need to be incorporated into the floor slabs/raft foundations.

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 a new vehicle access road and hardstandings are proposed at the site.

California Bearing Ratio (CBR) tests have not been carried out, but based on experience and published guidelines, a CBR value of at least 10% is considered appropriate for preliminary design purposes, for the near surface weathered bedrock. Actual design values should be determined for designated areas as required. The possible use of geo-grids within the road construction to mitigate subsidence risks (see Section 8.2.2) should be considered in pavement design.

The near surface weathered bedrock is considered to be non-frost susceptible.

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.

8.7 Excavation and Dewatering

Remnant foundations for the former Tudor Inn are believed to remain within the ground. Such foundations could be encountered in the area of the proposed apartment block in the north-west of the development.

Coal Measures bedrock was encountered at very shallow depth (less than 0.5m) across much of the site. See Section 8.2.4 for further discussion.

For shallow excavations where there is no danger to life, support of excavation sides is unlikely to be necessary across much of the site. Should indication of excavation instability be noted at any depth, support should be provided as appropriate. Instability of any excavations into the suspected end-tipped materials on the south-western boundary should be expected (see Section 8.2.5).

Based on our understanding of the proposed development, no significant groundwater ingress is 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 three test pits excavated across the site (TP1, TP5 and TP7). The results of the testing are presented in Appendix H.

Sufficient infiltration was achieved within the test to allow an infiltration rate to be calculated in two test pits (TP1 and TP5), but insufficient infiltration was experienced to allow an effective extrapolation of the test data to obtain an estimate of the likely infiltration rate in TP7. No infiltration rate can be calculated for this location. The calculated and extrapolated infiltration rates are presented in Table 7 below.

Table 7: Summary of Soakaway Infiltration Test Results

SA Test	Test Pit	Test depth	Measured Infiltration Rate[1]	Estimated Infiltration Rate[2]	Infiltration Soils
SA1	TP1 Fill 1	0.6m	1×10^{-5}m/s	n/a	Sandy gravel, cobbles and boulders (weathered bedrock)
SA2	TP5, Fill 1	0.6m	4×10^{-5}m/s	n/a	Sandy gravel, cobbles and boulders (weathered bedrock)
SA3	TP5 Fill 2	0.6m	2×10^{-5}m/s	n/a	Sandy gravel, cobbles and boulders (weathered bedrock)
SA4	TP7 Fill 1	0.5m	Test failed		Sandy gravel, cobbles and boulders (weathered bedrock)

Notes to Table 7:
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, but did fall beyond 75% fill depth, allowing extrapolation of data to 25% fill depth to provide an estimate of infiltration rate. Results should be treated with caution.

The soakaway infiltration rate is dependent on the fine fraction within the soils. All three test locations appeared visually to comprise similar soils (weathered bedrock in the form of slightly sandy gravel with cobbles and boulders). The results from Tests TP1 and TP5, indicating an infiltration rate of around 10^{-5} m/s, which is similar to that expected from such strata. The result from TP7, with only a marginal fall in water level in 3 hours, appears to be unrepresentative of the general weathered bedrock materials and may be indicative of pockets of finer materials present local to that area.

In general, we would recommend that 10^{-5}m/s be used as a typical infiltration rate for the upper layers of the weathered bedrock across the site. However, it must be appreciated that (as identified in TP7) some areas are likely to have significantly lower infiltration rates. We also advise that the soakaway testing was not completed in accordance with current SAB requirements, where three fills are required in each pit on the same or consecutive days.

Given the above, we recommend that once preferred soakaway positions are determined, further testing be undertaken in accordance with SAB requirements, to confirm the design rates at these locations. Hydraulic breakers are likely to be required to excavate a sufficiently deep hole in the bedrock for the soakaway drainage.

8.8.2 Soakaway Location

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 (e.g. that above the quarry face in the south of the site).

Soakaways should also not be constructed within 10m of any significant Made Ground materials such as those encountered in TP9 (in the south-western margins).

8.8.3 Soakaway Discharge

As the soakaway is located more than 18m from the nearest surface water course, a discharge consent should not be required. However, prior to construction, this should be confirmed with Natural Resources Wales.

The infiltration stratum at the site would be the Coal Measures bedrock, which is classed as a Secondary A aquifer, and the groundwater within is vulnerable to pollution. NRW have a general policy that no direct discharge of surface run-off would be accepted in vulnerable groundwater aquifers. Given the shallow depth of the bedrock at the site, any soakaways would result in the direct discharge of surface water run-off into the aquifer. We recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site. As a minimum, risk mitigation measures such as oil interceptors are likely to be required.

9 Recommendations

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

Required Further Actions:

- Obtain up to date information on underground services (Section 2.1);
- Asbestos sampling from stockpile and surrounding surface soils (Section 7.1.1);
- Sampling and testing of any surface soils beneath stockpile for asbestos (Section 7.1.1);
- Further sampling and testing in areas of identified past burning in garden areas (Section 7.1.2);
- Inclusion of this report within Health and Safety File for development (Section 7.1.4);
- Detailed risk assessment for hazardous ground gas, including installation and monitoring of wells in any abandoned mine workings identified (Section 7.3.1);
- Preparation of a Materials Management Plan (MMP) for re-use of soils on site and WM3 assessment of soils to be disposed of/re-used off-site, followed by WAC testing if disposal to landfill (Section 7.5.1).
- Further rotary open hole drillholes to determine the depth, thickness and status (coal or workings) of the Graigola coal seam beneath the site. At this stage, we consider that eight further drillholes to a maximum 15m depth would be appropriate. (Section 8.2.2).
- Further trial pitting in the south-western margins to define extent of loosely tipped fill materials (Section 8.2.5).
- Clearance of vegetation to allow access to former quarry face to allow a geotechnical inspection and assessment (Section 8.2.6).

Recommended Further Actions:

- Verification testing of any soils imported to site (Section 7.5.2).
- WM3 assessment of soils to be disposed of off-site (Section 7.5.1).
- Survey for Japanese Knotweed, particularly along the south-western boundary (Section 8.1.2);
- Careful watching brief during development for unrecorded mine entries across the site (Section 8.2.3);
- Careful design of drainage to minimise excavation into very shallow bedrock (Section 8.2.4);
- Measure CBR values at sub-grade prior to pavement construction (Section 8.6).
- Enquiries to NRW to confirm acceptance of soakaways and any risk mitigation measures required (Section 8.8.3).

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