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AFAN VALLEY

**Geomorphology
Assessment and Ground
Investigation Scoping
Report (GISR)**

(Reserved Matters Application)

Report Reference: ESP.8053.3708-02

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Proposed Adventure Park Afan Valley Resort

Geomorphology Assessment and Ground Investigation Scoping Report (GISR)

(Reserved Matters Application)

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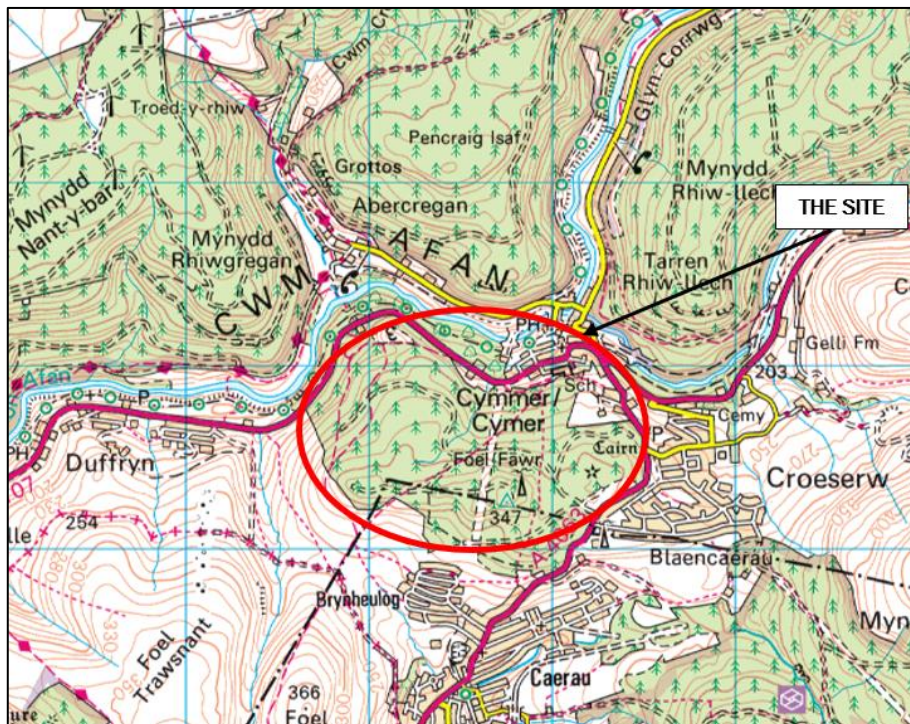
1.0 INTRODUCTION

BACKGROUND

- 1.1 The Wildfox Resorts Afan Valley Ltd., (hereafter known as the Client) are proposing to redevelop the subject site for leisure purposes. The Earth Science Partnership Ltd (ESP) were instructed by Stantec UK Ltd., acting on behalf of the Wildfox Resorts Afan Valley Ltd., to undertake a Geomorphology Assessment and Ground Investigation Scoping Report (GISR) which is presented in this document.
- 1.2 The site location is shown on Insert 1, the site boundary for this assessment is shown on Figure 1. The proposed development will comprise a large mixed use adventure resort comprising up to 600 lodges/apartments, a hotel, restaurants, retail units, leisure activities and other outdoor sports which are in the early stages of planning. The proposed development layout is presented as Figure 2.
- 1.3 Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2020).

SITE LOCATION

- 1.4 The site is located on the southern side of the Afan Valley, south of Cymmer, north of Caerau and west of Croeserw, South Wales. The National Grid Reference for the centre of the site is 285523 195668 and covers an area of approximately 130 hectares (Ha). The general site location is shown on Insert 1 below.



Insert 1: General Site Location from Ordnance Survey 1:50,000 scale map.
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- 1.5 The site is located on Foel Fawr, south of Cymmer and generally comprises undulating high ground, locally very steep. The majority of the site is currently covered with recently cut coniferous forest represented by stumps and brushwood, with some stands of coniferous forest still present locally in central and eastern areas. Access is gained via the eastern boundary with a track providing vehicular access through the centre of the site.
- 1.6 The western and northern boundaries are typically governed by the A4107, Brytwn Road and several private properties along it. The eastern boundary is partly the A4063 and private property in the northeast. The southern boundary of the site is part formed by the boundary between Local Authority areas, with Neath Port Talbot County Borough Council and Bridgend County Council.
- 1.7 A covered reservoir and telecommunications mast are located within the main site boundary, we understand that the land associated with these is not considered to be on site.

GEOMORPHOLOGY ASSESSMENT AND GROUND INVESTIGATION SCOPING REPORT SCOPE OF WORKS

- 1.8 The objective of this Geomorphology Assessment and Ground Investigation Scope Report (GISR) is to review previous investigation and assessment information provided to date and provide an updated detailed proposed scope of investigation specific to the site.
- 1.9 As part of the assessment, further information to support the scoping document was collected, and a geomorphological and landslide hazard assessment was carried out, which included a review of aerial photographs (stereo pairs), InSAR data and a geomorphological walkover.
- 1.10 The updated information is to be used to provide an updated Ground Model and develop a constraints plan for the proposed development.
- 1.11 Outline Planning Permission has been granted subject to conditions by Neath Port Talbot County Borough Council (NPTCBC) in January 2022 (Planning Application Reference P2018/0493). We have been informed Conditions 25, 26 and 29 need consideration as a priority. These conditions include consideration to the presence and impact avoidance of peat (Conditions 25 and 26) and contamination (Condition 29) (NPTCBC, 2018).
- 1.12 The scope of works for this assessment was mutually developed with the Client by ESP within an agreed budget. 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 28th March 2022 (ref: 8053 – ESP Offer Letter Rev 4 - GISR).
- 1.13 The assessment was undertaken between March and June 2022.

REPORT FORMAT

- 1.14 This report includes a summary of the site setting and review of previously assessments and investigations (Section 2), and details of the site constraints (Section 3). A summary of the geo-environmental site setting is provided in Section 5.0, however, it should be appreciated that this is a preliminary evaluation only.
- 1.15 A preliminary geotechnical ground model, identifying potential geotechnical hazards from information to date is presented as Section 4, including assessment of risks associated with coal mining, landslides and subsidence. The findings of Section 4 and Section 5 are to be updated following ongoing ground investigation works. A geotechnical risk register is provided in Section 6 and the

proposed ground investigation works, and additional recommendations are presented in Section 7.

- 1.16 Parts of the assessment and report, notably the geomorphology elements and landslide hazard identification and assessment were carried out in collaboration with Steve Parry¹ of Parry Engineering Geological Services Ltd (PEGS).
- 1.17 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) and the Welsh Local Government Association and Environment Agency (2012). This report is issued as a digital version only.

LIMITATIONS OF REPORT

- 1.18 This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed 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.
- 1.19 The assessment has been undertaken using the information provided to ESP. Additional sources of information are referenced throughout this report as required¹.
- 1.20 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.
- 1.21 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.
- 1.22 This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.
- 1.23 The site walkover elements of the desk study was limited due to access by thick vegetation and where this has potential limited recommendations is detailed in the text.

SOURCES OF INFORMATION

- 1.24 The report has been prepared using the information provided by the Client as outlined below:
- Ashfield Solutions Group (2021) Specification for Ground Investigation Works (132621-S01);
 - AECOM Limited (2017) Coal Mining Assessment Report (AECOM, 2017).
 - AECOM Limited (2017) Initial Peat Survey (AECOM, 2017).

1. ¹ Co-editor of: Developments in Engineering Geology. Geological Society Special Publication. 2016. Author of: Landslide hazard assessments: problems and limitations. Examples from Hong Kong. 2016. Chair of the IAEG commission C25 'Use of Engineering Geological Models'. Member of the European Federation of Geologists' 'Group of Experts' on Natural Hazards and Engineering Geology. Member of the International Association of Geomorphologists' Working Group on Applied Geomorphological Mapping.

- Breakwell Sumner Partnership Limited (BSP) (2017) Geo-Environmental Phase I Desk Study (Ref. 16255).
- Terra Firma (Wales) Limited (2017) Afan Valley Development – Landslip Potential (Ref. GCL/14536/Let1).
- AECOM Limited (2018) Summary of Findings in Relation to Peat Survey (AECOM, 2018).
- Terra Firma (Wales) Limited (2018) – Preliminary Findings, Peat Survey (Ref. DE/14510/Let2).

1.25 These documents and report are provided in Appendix E.

1.26 Additional updated information was obtained by ESP as outlined below;

- Groundsure (2022) Historical Mapping (small and large scale) (ESP-8597136_SS_1_1) Appendix A;
- Groundsure (2022) Environmental and Geological Insight Report (ESP-8597137) Appendix B;
- Welsh Government (2022) Aerial Images (no reference) Appendix C;
- Terramotion (2022) InSAR Data (no reference) Appendix I; and
- Coal Authority (2022). Consultants Mining Report (Ref. 51003007499001) Appendix F.

2.0 SITE SETTING

- 2.1 The information presented in this section was obtained from previous desk-based research and new sources as detailed in the text, including historical maps, a mining report obtained from the Coal Authority. Reports from previous ground investigations and assessments have been included throughout this report.
- 2.2 The site description is based on a series of walkovers, but largely based on a field reconnaissance and geomorphological site inspection visit made at the site on 13th and 14th April 2022 during overcast and intermittent weather.

SITE DESCRIPTION

- 2.3 The site is located on the northern flank of Foel Fawr, immediately south of Cymmer occupying an area of approximately 130ha. The highest point is in the southern central area at an elevation of 347.14m AOD (at a trig point) with the majority of the site sloping north and northwest, occasionally steeply, towards the River Afan. The northwestern boundary is at an elevation of approximately 170mAOD rising to approximately 220m AOD towards at the north-eastern boundary extent.
- 2.4 The site is currently largely undeveloped and generally comprises recently cut coniferous forest represented by stumps and brushwood with areas of open moorland in the eastern extent. A forested area remains in the northeastern to central extent.
- 2.5 A telecommunications mast and associated infrastructure are located in the southern and most elevated extent and a covered reservoir is located in the southeast. Two ponds are located in the southeast, surrounded by soft and marshy/peat ground. In the southwest extent, leaning (approx. 20° off vertical) overhead electricity cables were noted.
- 2.6 The site is currently accessed from the east off Maesteg Road (A4063), with vehicular access across the site gained via gravel tracks. Various smaller paths branch off the main access track allowing foot access however, large portions of the site remain relatively inaccessible.
- 2.7 A disused railway tunnel is located below the site generally trending north to south across the central portion. Recent mapping indicates that the northern entrance to the tunnel is located to the north of a public transport bus station north of the site boundary (immediately north of Brytwyn Road/A4017). The southern entrance to the tunnel is located some 800m south of the site on the northern margins of Caerau. The elevation of the north and south access points are at approximately 190 and 192 mAOD respectively. Based on the current ground levels, the tunnel is anticipated to be at significant depth across the majority of the site, from ground level at the north to approximately 145m depth at the southern boundary.

SITE HISTORY

Published Historical Maps

- 2.8 A review of the site history has been undertaken within the previous Phase 1 Desk Study (BSP Consulting, 2017). ESP have reviewed the information provided and undertaken further assessment including a review of updated historical Ordnance Survey County Series and National Grid maps. Extracts from the historical maps are presented in Appendix A.

- 2.9 In the wider vicinity of the site, the land to the west was and remains largely undeveloped with the exception of rail of coal mining infrastructure. Cymmer to the north is a well established town with residential and historic coal mining infrastructure. While the town of Croeserw to the east became more developed in the 1950/1960's comprising predominantly residential land-use. The site itself remains largely undeveloped to date with the exception of the historic Pen Y Castell buildings and more recent telecommunication mast, these are discussed further in the sections below alongside other salient information obtained from the historical map review.

Vegetation

- 2.10 As early as 1877 the northwest boundary is indicated to be covered by shrub, the remainder is shown as rough pasture. In 1965 an area of forest has been planted south of the site, partially encroaching the southeast boundary. Between 1972 and 1987, the majority of the site is shown to be covered by coniferous trees which are no longer shown in 1993.

Cymmer Tunnel

- 2.11 The Cymmer Tunnel is shown in its current alignment in the earliest mapping from 1876-1877. The tunnel is noted to be 'in construction' in the first maps. From 1971, the railway at the northern entrance is shown as dismantled and from 1986 the tunnel is shown as disused.

Former Quarries

- 2.12 From 1897, three quarries are shown at the central-northern boundary within the site. Further small quarries are shown immediately north and northeast of the boundary. From 1914, the western most is shown as old and from 1947, the remaining quarries on site are shown as old. In 1986, a track is shown to cut through one of the old quarries in the northeast. The off-site quarries immediately northeast are shown until 2010.
- 2.13 Three old quarries and one quarry are shown in the central site portion in the 1897 mapping. In 1899 the quarries are no longer labelled.
- 2.14 In 1962 most northernly quarry is no longer shown (likely backfilled) and in 1972 a new track is shown to traverse one of the former quarries. Depressions are noted on the LiDAR imagery in the general locations of these former quarries with the exception of the most northernly quarry which is less well defined.

Adits & Mine Shafts

- 2.15 Dyffryn Colliery (level and trial level) is shown 700m south in the earliest mapping in 1876 and subsequently disused /old from 1897.
- 2.16 Between 1897 and 1919, Glyncymmer Colliery is indicated immediately north with a coal level off site and an air shaft within the site boundary. The air shaft is not shown in the 1919 mapping. The infrastructure is not referenced beyond this date.
- 2.17 A trial level is shown on the first map, dated 1877 just beyond the east of the site. The 1897 map labels it as old.

Cracks/Fissures

- 2.18 An arcuate feature is indicated immediately south of the location of the existing mast, mapped as exposed rock, slopes and possible loose rock. The large feature trends generally east to west, with a second small feature with a similar trend towards the southwest and a north-south trending small feature to the north. The smaller feature southwest is only shown in 1899. From 1919, the arcuate feature is not shown as being continuous in its central portion.
- 2.19 A series of linear east to west trending features are indicated in the southeastern extent indicated to be loose rock/boulders and exposed rock (cliff type features). The features are indicated from the earliest mapping in 1877. The 1962 mapping indicates that rough grass is present within the largest linear (fissure type) feature. The southernmost feature is extended towards the west from 1971.

Reservoirs

- 2.20 A reservoir is shown in the central portion of the site in 1897, the feature remains until at least 1964-65. A reservoir and access track in the southeast is shown from 1962 and is shown to be covered from 1986. Although not shown on the recent mapping, the reservoir remains at the time of this report.

Structures

- 2.21 Prior to 1961, the area of the mast is occupied by a trig point (pillar) and from 1971 a lookout tower is indicated. In 1986, the lookout tower is not labelled, and a mast is indicated immediately east.

Pen y Castell

- 2.22 Crag and loose rock are shown at Pen y Castell in the northwest extent from 1878, at the time the land to the north and west is largely forested however this is later indicated to be rough pasture from 1919.
- 2.23 Small buildings (possible farmstead) are indicated immediately southeast of Pen y Castell hill and crags from as early as 1878. The buildings are no longer shown in 1987.

Ponds

- 2.24 From 2001, two ponds are shown in the south eastern site extent, west of the covered reservoir.

GEOLGY

Regional Geology

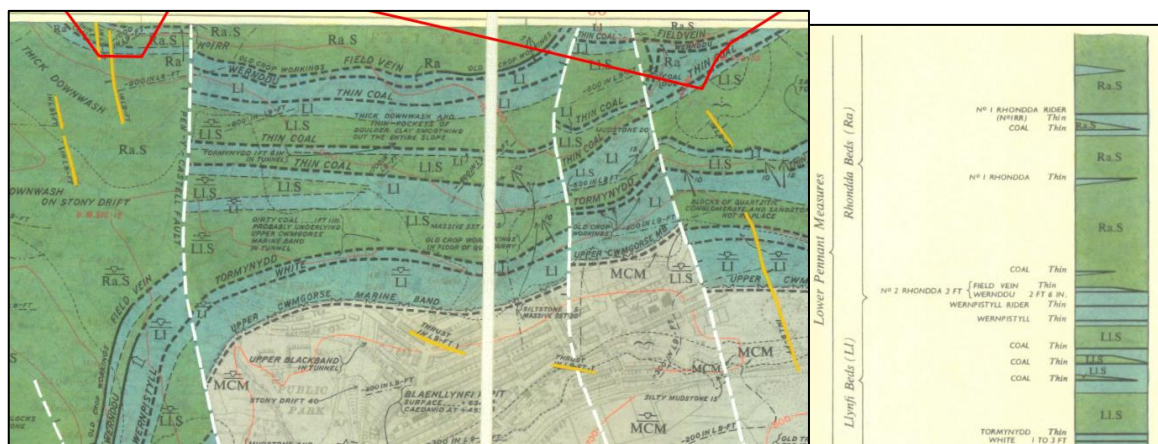
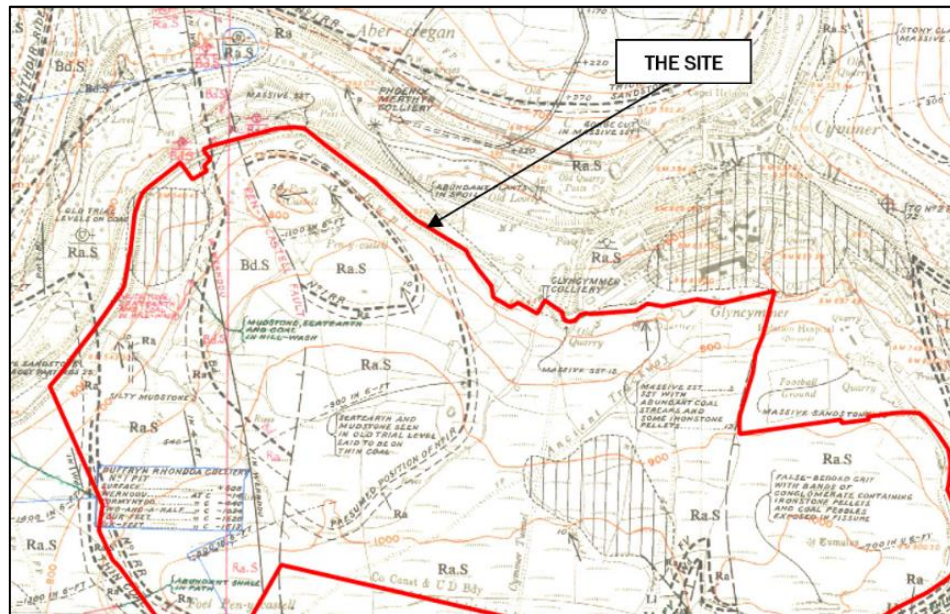
- 2.25 The Upper Coal Measures, now the Pennant Measures, in South Wales outcrop within a large east to west trending synclinal basin with subsidiary folds and faulting, forming an upland plateau with deeply incised river valleys (South Wales coalfield).
- 2.26 The Upper Coal Measures were deposited in the Carboniferous period within a fluvio-deltaic environment. The cyclical sedimentary succession consist of coarsening upwards series of mudstones, siltstones and fine-grained sandstones, seatearths and coals. Periodic intrusion of the sea during deposition created numerous marine bands.

- 2.27 Variscan deformation resulted in extensive post-deposition deformation (folding and faulting) though this is largely confined to the Lower and Middle Coal Measures, whilst the Upper Coal Measures remains relatively undeformed. The most common structural faults in the coalfield generally trend northwest to south east.
- 2.28 Devensian glaciation occurred across Wales with the Welsh Ice extending to south Wales which resulted in deep excision of the valleys, oversteepening of valley sides and extensive deposition glacial drift deposits.

SITE GEOLOGY

Published Geological Mapping

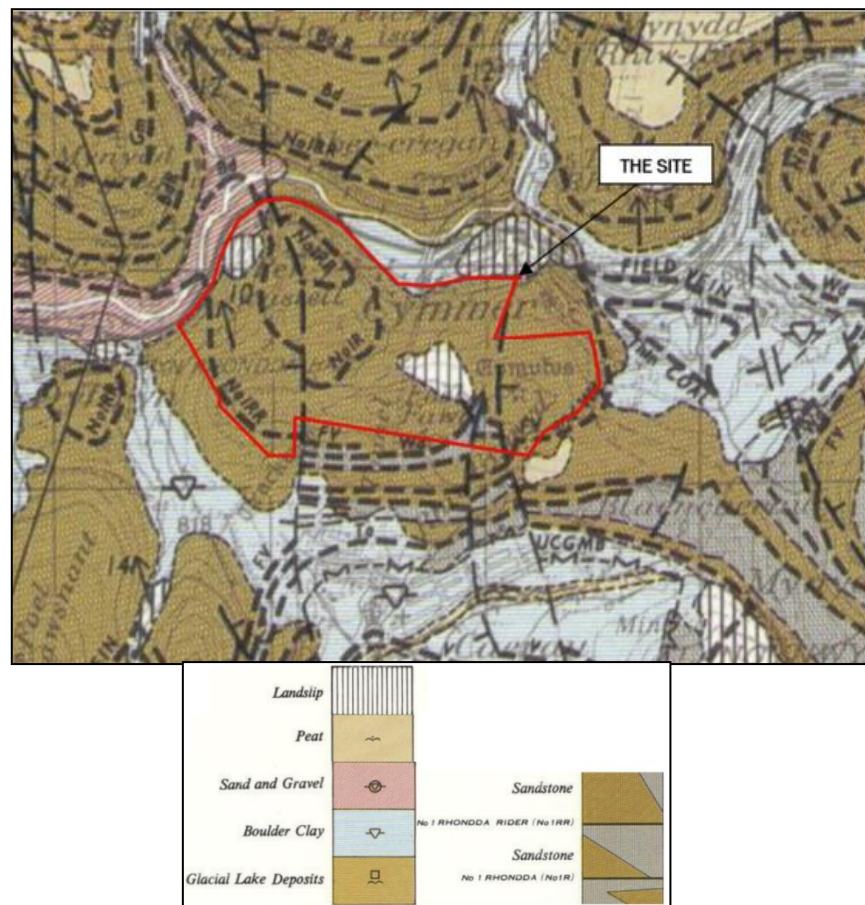
- 2.29 The published 1:10:560 scale geological mapping of the area (Sheets XXVI NW, 1947 and XVII SW, 1959, Insert 2a and 2b) indicates the site primarily be underlain directly by Upper Coal Measures bedrock, Lower Pennant Measures comprising the Brithdir Beds, Rhondda Beds and Llynfi Beds.
- 2.30 The majority of the site is directly underlain by Rhondda Beds sandstone with the Llynfi Beds underlying, shown to outcrop south of the site and partially encroaching the southeaster extent. The No. 2 Rhondda coal seam forms the boundary between these strata. The Brithdir Beds are shown to outcrop in the north western extent of the site.
- 2.31 There are 6no. records of bedding dip and dip direction within the site. Four of these suggest a dip amount of 10° below the horizon and dip direction towards the north and northwest.
- 2.32 A measurement of the bedding about 100m to the east of Pen y Castell (dwelling) has a dip amount of 12° and dip direction of northwest. The bedding near the summit of Pen y Castell (northwest of the site) was measured to have a dip of 20° below the horizon toward the west.



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|------|--|
| 2.33 | Reference to the 1:50,000 scale mapping (Sheet 248, 1975) (Insert 3) and up to date mapping available on the website of the British Geological Survey (Geology of Britain Viewer, BGS, 2022) indicates a similar succession, but the Boulder Clay has been renamed Glacial Diamicton and the Sand and Gravel renamed as Glaciofluvial Deposits. Peat is indicated immediately beyond the southeastern boundary. The Lower Pennant Measures are renamed Pennant Sandstone Formation and Rhondda/Llynfi Beds, renamed Rhondda/Llynfi Member. |
| 2.34 | Glacial Diamicton is indicated in the central northern extent and Glacial Sand and Gravel in the northwestern extent. Landslip deposits are shown in the central/eastern and northwest portions. |
| 2.35 | The Rhondda Member strata would be expected to comprise principally green-grey lithics arenites (Pennant sandstones) with thin mudstone, siltstone, seatearth interbeds and thin seams of coal. The base of the Member is placed at the base of the No.2 Rhondda Coal seam. The 1:10,000 mapping indicates that locally the Rhondda Member contains abundant coal streaks and some |

ironstone pellets. The Llynfi Member would be expected to comprise similar strata with the upper portions often observed as seatearth and mudstone. The top of the Llynfi Member is taken at the base of the No. 2 Rhondda coal seam, directly underlain by thin seatearths and mudstone (Waters, et al., 2009).

- 2.36 Numerous coal seams are indicated to outcrop at the site. The coal mining setting is discussed further in sections below. The geological setting is present in Figure 3. A summary of the coal seams indicated in the vicinity of the site is provided in Table 5.



Insert 3: Extract from BGS Geological Map Sheet 248 original 1:50,000 scale (1975).
Reproduced with permission (BGS licence number: C15/05 CSL).

- 2.37 A number of north to south trending faults are shown including the Pen-y-Castell fault in the western portion. The Pen-y-Castell fault is indicated to be a normal fault, with down-throw to the west recorded between 160 to 180m. North-south normal faults are indicated in the eastern extent, which are indicated to have a down-throw to the west and east on the geological mapping. Reference to abandonment plans indicates displacement of between 2.5 and 8.5m. A smaller north western south eastern trending fault in indicated near the south of the site.

Published Geological Memoirs

- 2.38 Reference to the geological memoir for the area (Woodland and Evans, 1964) provides further details of the anticipated geology as summarised below.

- 2.39 The Pennant Measure cyclothems (cyclical strata successions) differ from those of the Lower and Middle Coal Measures. The Lower Pennant Measures are generally formed of significantly thicker continuous sandstone strata lying immediately upon or close to coal seams, mudstone strata may be present between the sandstone and coal seams.
- 2.40 The predominantly argillaceous Llynfi Beds (Member) within the lower Afan Valley generally include two thin coal seams which have been locally mined, The Wernpistyll and the Wernpistyll Rider, are generally found at between 80 to 135ft (approximately 24.0 to 41.0m) and 30 to 50ft (9.0 – 15.2m) respectively, below the top of the group. The coal seams are separated with mudstones and thin sandstones.
- 2.41 The base of the Rhondda Beds (Member) is marked by the No. 2 Rhondda coal seam which is heavily worked. Locally the seam is split with the lower coal (No. 2 Rhondda/Wernddu/Rock Fawr or Malthouse) generally between 3 to 4ft thick (0.9 – 1.2m). The upper coal (Field Vein) is approximately 2ft thick (0.60m) and has been found to be separated from the lower coal by as much as 120ft (36.5m). Local to the Afan Valley, the No. 1 Rhondda is noted to be discontinuous affected by washouts. The No. 1 Rhondda Rider is found across most of the area.
- 2.42 The Brithdir Beds are typically arenaceous with thin coal seams, including the Brithdir and Brithdir Rifer coal seams which are generally not of significant working thickness or quality with only sporadic records of workings.

Landslides

- 2.43 The following landslides are recorded on the geological mapping (Sheet 248 and Sheet XVI NW). The reference number adopted related to the UK National Landslide Database (NLD) (maintained by the British Geological Survey (BGS)). The BGS mapped location of the landslides are displayed on Figure 3.

Table 1: NLDB Features in site

NLD No	Name	Detail
3632	Foel Fawr (SWC: AA17)	Located 0.7km southwest of Cymmer on the north flank of Foel Fawr.
3624	Cymmer (SWC: AA16)	Located on the south slope of the Afan valley opposite Glyncorrwg.
3633	Pencastell Bungalow (SWC: AA18)	Located on the south side of the valley on a northwest facing slope, 50m south of Pencastell Bungalow above A4107 Afan Valley road.

HYDROGEOLOGY

Hydrogeological Setting

- 2.44 The Upper Coal Measures forms a large synclinal basin that contains large quantities of water. Historically the Upper Coal Measures were divided to a number of aquifers in the sandstone bedrock divided by the lower permeability mudstone horizons.

Anticipated Groundwater Bodies

- 2.45 Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the Pennant Sandstone Formation bedrock strata. However, localised perched water bodies cannot be discounted.
- 2.46 A groundwater body near the ponds and surrounding area of peat in the southeastern area of the site is likely.

Groundwater Movement

- 2.47 Groundwater movement within the superficial deposits (Glaciofluvial Deposits and Glacial Diamicton) will be controlled by intergranular flow whilst, in the Pennant Sandstone Formation, fracture flow is likely to be dominant. The site is in an area influence by general north to south trending normal faults which will impact the groundwater movement across the site.
- 2.48 Reference to Hydrogeological Map 17 (BGS, 1986) indicates that the Upper Coal Measures sandstone is hard and dense with a low porosity of typically 2%, and locally lower where deformation (folding/faulting) has resulted in secondary cementation. Discontinuities within the bedrock create secondary permeability, allowing vertical (downward) movement and storage of groundwater. Mudstone beds with relatively low permeability act as barriers, preventing vertical movement of water.
- 2.49 The extensive disturbance and deformation of the rock caused by the extraction of coal has effectively resulted in hydrogeological continuity of the sandstone aquifers across the Upper Coal Measures. It should be appreciated that in former mining areas, such as this, groundwater conditions may still be changing in response to the cessation or reduction in pumping from underground coal workings.
- 2.50 The main groundwater body is anticipated to be within the Pennant Sandstone Formation bedrock likely at depths greater than 10m. The primary hydraulic gradient is anticipated to flow towards the River Afan to the north/northeast and given the site setting, we consider that the groundwater within the bedrock aquifer may be providing base flow to the River Afan.
- 2.51 A possible shallow groundwater body is anticipated to be present near two ponds located in the eastern portion of the site. Deep peat has been noted to surround these ponds and a perched, shallow groundwater body is likely to flow through the peat toward the ponds at a relatively slow rate.

Aquifer Classification

- 2.52 Reference to the aquifer maps published in the environmental and geological data report (Appendix B) indicates that the Glaciofluvial Deposits in the northwest extent are classed as Secondary A and the Glacial Diamicton Deposits in the central northern extent are classes as Secondary Undifferentiated. The remainder of the site is not indicated to be underlain by superficial deposits. The bedrock (Pennant Sandstone Formation) is classed as Secondary A Aquifer.
- 2.53 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.

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

Abstractions and Groundwater Vulnerability

- 2.55 The environmental data report (Appendix B) indicates that there are no groundwater abstractions or Source Protection Zones within 500m of the site.
- 2.56 The groundwater vulnerability is shown in the environmental data report (Appendix B) to be secondary bedrock aquifer, high vulnerability.

Groundwater Chemistry

- 2.57 Groundwater within the Coal Measures varies from good quality with low total dissolved solids to highly mineralised. Within the Upper Coal Measures (Pennant Measures), sulphate concentrations generally increase with depth (BGS, 1986).
- 2.58 It should be noted that localised variations in groundwater quality occur and will likely be affected by past coal mining.

HYDROLOGY

Surface Water Features

- 2.59 The nearest major surface water feature to the site is the River Afan which generally flows to the west and southwest approximately 200m west and north of the site at its closest point. A number of streams are indicated in the western extent of the site, observed as slow running during geomorphological mapping, and two ponds are located in the south eastern extent, (Appendix B).
- 2.60 The ponds in the east of the site is associated with an area of peat indicated by previous assessments.
- 2.61 A covered drinking water reservoir is located on site.

Surface Water Abstractions

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

FLOODING

Rivers and Seas

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

- 2.64 The potential for flooding from rivers or seas has not been addressed further in this report and if required ESP are able to implement an appropriate Flood Consequences Assessment.

Surface Water

- 2.65 Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. This type of flooding can be difficult to predict, much more so than river or sea flooding as it is hard to forecast exactly where or how much rain will fall in any storm. The information available depends on available records including ground levels and drainage.
- 2.66 From a review of information available on the Natural Resources Wales (NRW) website (2022), the majority of the site is located in Flood Zone 1 and not indicated to be at risk flooding from rivers (fluvial) or seas (tidal). Flood Zone 1 is defined as an area during any given year that has less than 0.1% (1 in 1000) of flooding from rivers (fluvial) or seas (tidal).
- 2.67 However, isolated areas are indicated to be at low to high risk where streams and ponds are present.
- 2.68 A Low risk means that in each year, the area has a chance of flooding of between 0.1% (1 in 1000) and (1%) and 1 in 100.
- 2.69 A medium risk means that each year, the area has a chance of flooding of between 1% (1 in 100) and 3.3% (1 in 30).
- 2.70 A high risk means that each year, this area has a chance of flooding of greater than 3.3% (1 in 30).

Groundwater

- 2.71 Groundwater flooding is defined as the emergence of groundwater at the ground surface away from river valleys or the rising of groundwater into man-made ground under conditions where the 'normal' range of groundwater levels and groundwater flows is exceeded and predicted risk from groundwater flooding aims to identify locations where this form of groundwater flooding could happen. It does not incorporate anomalous discharge from springs leading to groundwater flooding down the topographic slope or flooding associated with urban groundwater rebound, mine water discharge, urban drainage, or any other flooding associated with changes in the engineered environment.
- 2.72 The environmental and geological data report (Appendix B) indicates that the majority of the site is not at risk from groundwater flooding however, a small portion in the northwestern extent and northern extent are shown to be Low risk.

3.0 KNOWN SITE CONSTRAINTS

SERVICES

- 3.1 The Client has provided ESP with a series of plans showing the locations of recorded underground services in the vicinity of the site. The services records are presented as Appendix D.
- 3.2 Site observations and the utility plans indicate that the site is crossed by the following services:
- 11kV electricity cables on pylons crossing the site;
 - Medium pressure gas mains along the eastern boundary, crossing the site in the southeast corner;
 - Water trunk main in the eastern extent generally crossing the site from north to south.
 - Openreach telecommunication cables in the south and southeastern extent and around the site boundary.
- 3.3 It is understood that in the southern central portion, ducting is in place for Openreach assets however, on site observations indicate that no cables are currently present within the ducting. The Principal Contractor (Keystone Environmental) informed ESP that fibre optic cables are located in the southeastern portion of the site that trend toward the telecommunication mast near the south boundary, or highest point of the site. Keystone Environmental had no drawings to show their location.
- 3.4 A covered reservoir is location in the southeastern extent of the site which is understood to provide water supply to the nearby towns of Cymmer and Croeserw. A water trunk main crosses the eastern extent of the site towards the covered reservoir in the southeast eastern extent.

ECOLOGY

- 3.5 The following reports have been provided by the Client with regards to the ecological setting at the site and are displayed in Appendix E:
- Afan Valley Adventure Resort – Environmental Statement Part C: Environmental Considerations – Chapter 8 Biodiversity. Author and year unknown.
 - Stantec. 2021. Wildfox Resort, Afan Valley. High Levels Ecology Strategy. Document Ref. 332310796/Ecol/001.
- 3.6 It is understood that the key ecological considerations at the site related primarily to common lizards, breeding birds, invasive non-native species and general land of ecological value. As part of the proposed development, two locations to the south (Solar Farm Site (SFS)) and southwest (Dyffryn Tips Site (DTS)) have been identified for use as a compensation strategy, specifically with relation to the relocation of reptiles and nightjars. The ecological impact and status of the site are being managed by ecological specialists (Keystone Environmental).
- 3.7 A number of constraints have been imposed for ground investigation works including:
- Proposed ground investigation points and access routes are to be agreed in advance and cleared of vegetation with the client team and Principal Contractor;
 - All works are to be overseen by an Ecological Clerk of Works (ECow) and pre-commencement inspection will be undertake prior to works starting (1 week and 2 days prior) and weekly therein.

- All excavations will either be infilled or covered at the end of each working day; and
- Prior to leaving the site all vehicles and footwear will be cleaned to prevent the spread of non-native invasive plant species.

3.8 A technical site constraints plan is presented as Figure 4.

ARCHAEOLOGY

3.9 The Client has supplied ESP with the following documents which are displayed in Appendix E:

- Dyfed Archaeological Trust (2017). Appendix 7.2. to Environmental Assessment – Afan Valley Adventure Resort. Neath Port Talbot – Archaeological Upland Survey Summary Report. Report Number: 2017/54.
- Dyfed Archaeological Trust (2018). Appendix 7.2. to Environmental Assessment – Afan Valley Adventure Resort. Neath Port Talbot – Historic Environment Desk Based Assessment. Report Number: 2017/13.

3.10 The assessments identified archaeological sites within the development boundary and two historic assets are considered to be of high archaeological importance, the Glyncymmer Bronze Age cairn and the Heol Y Moch trackway, which should be considered as part of the development.

3.11 Potential impacts from archaeology should be considered in more detail and constraints for site investigation and detailed development should be clarified.

3.12 A technical site constraints plan including archaeological constraints is displayed as Figure 4.

PEAT

3.13 Aecom (2017, 2018) have previously undertaken assessments of peat at the site as summarised below.

3.14 In December 2017, Aecom undertook a visual assessment of the whole site to set out areas of potential peat. This suggested six areas of where peat may be present, as shown on Figure 5a; some of these areas extended off site. Recommendations were given to undertake site investigation in each of the areas to identify peat and deep peat.

3.15 The second assessment, Summary of Findings in Relation to the Peat Survey (May 2018) includes the findings of a site investigation undertaken by Terra Firma (April 2018). Physical investigations identified a single area of deep peat i.e. those containing peat at a depth of, or greater than 0.5m which was located in the east of the site, as shown in Figure 5 of the Aecom report.

3.16 The report states that it understood that areas of peat greater than 0.5m thick are not to be developed as they present a valuable resource and are to be protected, these are areas of deep peat.

3.17 ESP have recently undertaken further site investigation works (Figure 5b), the findings of which are discussed within a separate report (Ref.8053.3717-03).

4.0 ADDITIONAL SITE ASSESSMENT – UPDATED GROUND MODEL

LIDAR

- 4.1 Light Detection and Ranging (LiDAR) is a remote sensing method that uses light in the form of pulsed lasers to measure ranges/distances to the earth from an airborne system. Many of these measurements along with the location of the instrument can then produce three-dimensional information about the shape of the earth, and thus provide us information on the site's morphology.
- 4.2 LiDAR data as a Digital Terrain Model (DTM) was obtained by ESP and is at a resolution of 1m. The greyscale shown on the figure is merely a way of delineating elevation and not set to a specific scale in this case. Dark grey is representative of lows/depressions with pale grey highlighting higher spots. The data is presented as Figure 6.
- 4.3 An initial review of the LiDAR data identified various areas of interest across the site including the identification of potential adit/mining features, preliminary landslide extents and large fissures and graben type features. The initial findings informed the basis of detailed geomorphological mapping to further investigate the features identified.

INSAR

- 4.4 Interferometric Synthetic Aperture Radar (InSAR) is a technique used to measure changes in land surface altitude. SAR satellites use active sensors that emit a signal to the earth and record the signal reflected (via scatterers) back to the satellite, recording the position of the earth's surface at the time of image acquisition and measuring the rate of change of elevation relative to a base data set.
- 4.5 InSAR data (APSYS) was obtained by ESP for the site dating between 2017 and 2022, including stereo data providing vertical (up-down) motion and lateral (east-west) motion of up to 30mm movement.
- 4.6 The spatial resolution output is understood to be 20m and as a result any deformation less than 20m in size may not be detected. This can increase in particularly rural areas where the data is subject to greater noise. The vertical resolution is however in the range of millimetres.
- 4.7 The data has been reviewed and presented within Figures 7a (vertical movement) and 7b (horizontal movement) and is discussed further as required.

AERIAL PHOTOGRAPH INTERPRETATION (API)

- 4.8 In order to examine the potential change in morphology of the site in more detail, and over the course of time; we have obtained and reviewed 2D and 3D (stereopairs) aerial photographs held for the site, this includes photographs held by the Welsh Assembly Government and aerial imagery available on online platforms, such as Google Earth. The photos reviewed are displayed in Appendix C.
- 4.9 The API was carried out using a Sokkisha stereoscope with x3 binocular attachments. The API was made on a basis of shape, pattern, size, tone/colour and texture together with morphological position.
- 4.10 The API had two key aims:

- to allow initial engineering geological and engineering geomorphological mapping of the site, and
 - to evaluate for any evidence of previous landslides in the study area and, if present, generate a site-specific landslide inventory.
- 4.11 The aerial photographs were imported into a Geographical Information System (GIS) and the images orthorectified to assist with the locations of features observed in the API.
- 4.12 The decision as to whether a geomorphological feature potentially represents a landslide is based on a combination of factors including sharpness of morphology, vegetation changes, location within the landscape, presence of debris and position with respect to a drainage line.
- 4.13 With time, a landslide will become less obvious as a result of the establishment of vegetation and the degradation of the scarp. The length of time a landslide will be sufficiently defined allowing it to be interpreted as such will largely depend on the volume of the original landslide, with larger scars requiring more time to degrade. With increasing degradation of the landform there is also increasing uncertainty with respect to whether the depression is the result of landslide processes and, if it is, whether the depression was formed by a single or multiple events.
- 4.14 The findings of the API are discussed where relevant throughout the sections below.

LANDSLIDES

Landslide Hazard and Risk

- 4.15 There are no UK standards for the assessment of landslide hazard and risk. However, Fell et al. (2008), reporting on behalf of JTC-1 (Joint Technical Committee on Landslides and Engineered Slopes, an IAEG, ISRM, ISSMGE collaboration exercise, i.e. all relevant international geotechnical societies) provides guidelines for landslide hazard and risk assessments. JTC-1 is broadly in line with AGS (2007) with minor modification for international practice.
- 4.16 The guidelines provide:
- Definitions and terminology for use internationally;
 - Description of the types and levels of landslide zoning;
 - Guidance on where landslide zoning and land use planning are necessary to account for landslides;
 - Definitions of levels of zoning and suggested scales for zoning maps taking into account the needs and objectives of land use planners and regulators and the purpose of the zoning;
 - Guidance on the information required for different levels of zoning taking account the various types of landslides;
 - Guidance on the reliability, validity and limitations of the methods; and
 - Advice on the required qualifications of the persons carrying out landslide zoning and advice on the preparation of a brief for consultants to conduct landslide zoning for land use planning.
- 4.17 The guidelines also provide the following definitions:
- Hazard** — A condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area), classification and velocity of the

potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time.

Elements at risk —The population, buildings and engineering works, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the landslide hazard.

Vulnerability — The degree of loss to a given element or set of elements within the area affected by the landslide. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is (are) affected by the landslide.

Risk — A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability of a phenomenon of a given magnitude times the consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form. For these guidelines risk is further defined as: (a) For life loss, the annual probability that the persons at risk will lose their life taking into account of the landslide hazard, and the temporal–spatial probability and vulnerability of the person (b) For property loss, the annual probability of a given level of loss or the annualised loss taking into account the elements at risk, their temporal–spatial probability and vulnerability.

Zoning — The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk or applicability of certain hazard-related regulations.

The guidelines note that “Qualitative methods are often used for susceptibility zoning, and sometimes for hazard zoning. When feasible it is better to use quantitative methods for both susceptibility and hazard zoning. Risk zoning should be quantified. More effort is required to quantify the hazard and risk but there is not necessarily a great increase in cost compared to qualitative zoning”.

4.18 Lee and Jones (2014) note that there are three broad types of risk estimation:

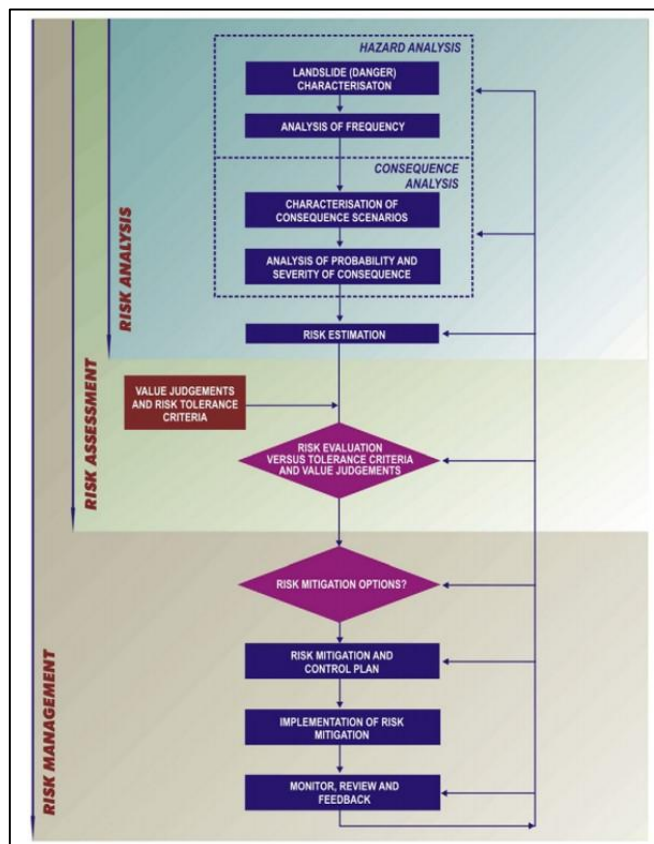
- Qualitative risk estimations are “those where both likelihood and adverse consequences are expressed in qualitative terms. They are therefore highly subjective estimations”
- Semi-quantitative risk estimations which are “combinations of qualitative and quantitative measurements of likelihood and consequence”
- Qualitative risk estimations (or quantitative risk assessments, QRA) which “combine values of detriment with probabilities of occurrence. It must be noted that such an approach frequently does not produce a single answer”

4.19 Whilst the AGS/JTC-1 guidelines were developed for hazard and risk zoning, i.e. assessing landslide hazard and risk for new developments, they are equally applicable for evaluating landslide hazard and risk to existing developments. Where appropriate, the AGS guidelines were used as the basis of this assessment.

4.20 JTC-1/AGS (2007) suggest the following stages for a landslide hazard and risk assessment:

- Hazard identification which comprises classification of landslides, extent of landslides (area and volume), travel distance of landslides and rates of movement;
- Frequency analysis comprising estimation of frequency, historic performance, relate to initiating events;
- Consequence analysis comprising elements at risk, temporal probability and vulnerability; and
- Risk calculation.

4.21 Once these steps have been undertaken an evaluation of risk and risk mitigation can be considered.



Insert 4: Framework for landslide risk management (Fell et al, 2008)

Landslide Classification

4.22 Landslides are typically classified in terms of material type (rock, debris, earth) and movement type (fall, topple, slide, flow) following the definitions of Cruden & Varnes (1996). However, landslides can be complex processes. For example, a landslide may initiate as a slide, disaggregate and become a debris avalanche, enter a drainage line and become a debris flow, enter a flatter area, deposit the coarse material but continue downstream as a debris flood. Hungr et al., 2001 noted problems with the use of the flow terminology as proposed by Cruden & Varnes (1996) and proposed amended terminology (Table 2).

Table 2: Classification of Landslide Types (after Hungr, et al., 2001).

Movement Type	Rock	Debris	Earth
Fall	1. Rock fall	2. Debris fall	3. Earth fall
Topple	4. Rock topple	5. Debris topple	6. Earth topple
Rotational sliding	7. Rock slump	8. Debris slump	9. Earth slump
Translational sliding	10. Block slide	11. Debris slide	12. Earth slide
Lateral spreading	13. Rock spread	-	14. Earth Spread
Flow	15. Rock creep	16. Talus flow	21. Dry sand flow
	-	17. Debris flow	22. Wet sand flow
	-	18. Debris avalanche	23. Quick clay flow
	-	19. Solifluction	24. Earth flow
	-	20. Soil creep	25. Rapid earth flow
	-	-	26. Loess flow
Complex	27. Rock slide-debris avalanche	28. Cambering, valley bulging	29. Earth slump-earth flow

- 4.23 Consequently, where a landslide is interpreted as involving “a rapid to extremely rapid flow of saturated non-plastic debris in a steep channel” (Hungr et al., 2001), it is classified as a debris flow, where it is interpreted as involving “very rapid to extremely rapid shallow flow of partially or fully saturated debris on a steep slope without confinement in a channel.” (Hungr et al., 2001), it is classified as a debris avalanche. As noted by Hungr et al., 2014 “the practical consequences of the distinction between debris flow and debris avalanches are obvious. A debris flow hazard study begins with the definition of the path and at least the lateral limits of the deposition area (fan). The path and the debris fan can be expected to contain evidence of past occurrences which can be used to derive information on magnitude and frequency. Debris avalanche studies, on the other hand, must examine tracts of steep slopes, many segments of which may not have experienced debris avalanches during the observable past”.

Qualitative Landslide Assessments

- 4.24 As discussed in previous sections, there is not considered to be a robust and widely used assessment criteria that can simply be adopted to undertake a preliminary qualitative assessment. Therefore, a modified assessment has been generated which is based upon terminology and qualitative descriptions used in the AGS 2007 guidance. It should be noted that the AGS 2007 qualitative assessment is for risk to property only.
- 4.25 The modified descriptions and risk rankings used in this assessment are presented below. Table 3 provides a qualitative measure of likelihood and Table 4 presents a qualitative measure of consequences.

Table 3: Qualitative Measures of Likelihood

Approx. Annual Probability			Implied Indicative Landslide Recurrence Interval (years)		Description	Description or	Level
Indicative Value	Notional Boundary						
10^{-1}			10		The event is expected to occur over the design life	Almost Certain	A
	5×10^{-2}			20			
10^{-2}			100		The event will probably occur under adverse conditions over the design life	Likely	B
	5×10^{-3}			200			
10^{-3}			1,000		The event could occur under adverse conditions over the design life	Possible	C
	5×10^{-4}			2,000			
10^{-4}			10,000		The event might occur under very adverse circumstances over the design life	Unlikely	D
	5×10^{-5}			20,000			
10^{-5}			100,000		The event is conceivable but only under exceptional circumstances over the design life.	Rare	E
	5×10^{-6}			200,000			
10^{-6}			1,000,000		The event is inconceivable or fanciful over the design life.	Barely Credible	F

Notes:

1. The above table is adapted from the AGS 2007 Appendix C tables.

Table 4: Qualitative Measures of Consequence

Description	Descriptor	Level
Structure(s) completely destroyed and/or large-scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	Catastrophic	1
Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	Major	2
Moderate damage to some of structure, and/or significant part of the site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	Medium	3
Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	Minor	4
Little damage.	Insignificant	5

Notes:

1.The above table is adapted from the AGS 2007 Appendix C tables.

2.The table primarily considers risk to property.

- 4.26 The associated levels from Table 3 and 4 are then used in Table 5 to provide a qualitative risk ranking and Table 6 provides example implications for each risk ranking.

Table 5: Qualitative Risk Analysis Matrix

LIKELIHOOD	CONSEQUENCE (TO PROPERTY)				
	1 Catastrophic	2 Major	3 Medium	4 Minor	5 Insignificant
A – Almost Certain	Very High	Very High	Very High	High	Medium or Low ²
B – Likely	Very High	Very High	High	Medium	Low
C – Possible	Very High	High	Medium	Medium	Very Low
D – Unlikely	High	Medium	Low	Low	Very Low
E - Rare	Medium	Low	Low	Very Low	Very Low
F – Barely Credible	Low	Very Low	Very Low	Very Low	Very Low

Notes:

1.The above table is adapted from the AGS 2007 Appendix C tables.

2.Further consideration required, see AGS 2007 Appendix C tables for clarification.

Table 6: Risk Level Implications

Risk Level	Example Implications ¹
Very High	Unacceptable without treatment. Extensive detailed investigation, research, planning and implementation of treatment options essential to reduce risk to low. May be too expensive or impractical. Work likely to cost more than value of property.
High	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to low. Work would cost a substantial sum in relation to the value of the property.
Medium	May be tolerated in certain circumstances (subject to regulator approval) but requires investigation, planning and implementation of treatment options to reduce the risk to low. Treatment options to reduce the risk to low risk should be implemented as soon as practicable.
Low	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.

Very Low Acceptable. Manage by normal slope maintenance procedures.

Notes:

1.The above table is adapted from the AGS 2007 Appendix C tables.

- 4.27 A qualitative assessment will be made using the information gained, which is to a large extent is governed by discrete points in time, i.e. when the aerial photographs were taken or when the area was resurveyed for the historical maps.
- 4.28 Whilst the historical maps have provided key information on the streams and mining features around the site, they do not show any movement of the landslides. Therefore, the assessment is largely based upon the period of time covered by the available aerial photographs.

Previous Assessment

- 4.29 A Landslip Potential Assessment has previously been undertaken (Terra Firma, 2017) and the information provided as part of this assessment has been reviewed by ESP. A summary of the assessment is provided below:
- The South Wales Landslip Survey (Conway et al, 1980) identifies two landslides within the site boundary, in the central portion and northwestern extent. Further details are provided in Table 3 below.
 - The landslides are indicated to be shallow translational and not deep seated.
 - The report states that “both landslips are located within some of the weakest rock structures in the South Wales coalfield, the argillaceous strata of the Rhondda Beds, and great care should be taken when working in this strata”
 - Shallow groundwater control is may ne required as part of development design and the addition of groundwater to the regime may initiate ground movement.
 - Detailed ground investigation is required to understand the groundwater setting at the site and an up-to-date geomorphological study of the landslides should be carried out.
- 4.30 The statements made in this assessment do not align with the updated conceptual ground model as discussed in later sections of this report.

Recorded Landslides – On Site

- 4.31 The UK National Landslide Database (NLD) is maintained by the British Geological Survey (BGS). The NLD was developed from work undertaken by the Department of the Environment (DoE) in the mid-1980s (Jones and Lee 1994). That database comprised a desk study, collating information from maps, journals, technical reports and books as well as university research and theses. The vast majority of these landslides were recorded as inactive or stable.
- 4.32 However, this study had several issues (Jones, 1998) key of which were:
- A bias of information in areas of conspicuous landslide activity, such as the South Wales Coalfield, Southeast England and the Jurassic escarpment.
 - Many of the landslides were extracted from BGS geological maps, and the emphasis on mapping superficial geology, and landslides, has varied greatly across the UK in the past.
- 4.33 As a result, the distribution of landsliding revealed by the study was considered to be an "*artefact of investigation reflecting varying degrees of ignorance*" (Jones and Lee, 1994).
- 4.34 BGS have expanded the original database, including data extracted from social media and the NLD contains attributes of 17,000 landslides, 10,000 of which are from BGS maps (Foster et al., 2008).
- 4.35 The NLD contains three records within or immediately in the vicinity of the site.

Table 7: NLDB Features in site

NLD No	Name	Detail
3632	Foel Fawr (SWC: AA17)	Located 0.7km south west of Cymmer on the north flank of Foel Fawr.
3624	Cymmer (SWC: AA16)	Located on the south slope of the Afan valley opposite Glyncorrwg.
3633	Pencastell Bungalow (SWC: AA18)	Located on the south side of the valley on a northwest facing slope, 50m south of Pencastell Bungalow above A4107 Afan Valley road.

- 4.36 The NLDB contains no other information on these features, However, Conway et al., (1980) record the following additional information for these features.

Table 8: Summary of Landslides within site boundary (Conway et al., 1980)

NLD No	Name	Conway et al., (1980) Description
3632	Foel Fawr (SWC: AA17)	Shallow translational debris slide in the Rhondda Sandstone with flows in the toe region. Dormant.
3624	Cymmer (SWC: AA16)	Slip completely covered by buildings, probably a shallow translational debris slide. Dormant.
3633	Pencastell Bungalow (SWC: AA18)	Shallow degraded and vegetated debris slide in superficial deposits, weathered Rhondda mudstone and Rhondda and Brithdir sandstone debris, Indistinct vegetated Brithdir Sandstone backscar with Brithdir coal approx. 30m upslope, Lower parts of slip are cut by A4107 road, Forested. Dormant.

- 4.37 The above landslides are recorded in the geological mapping as discussed above. The landslide locations are displayed on Figure 3.

- 4.38 Based on the API there is no evidence suggest that NLD features 3624 and 3633 are related to landslide processes.
- 4.39 NLD feature 3632 is interpreted a degraded rotational landslide. The main scarp of this feature coincides with the arcuate scarp recorded on the topographical maps, indicating it was present in 1877-78.
- 4.40 Above NLD 3632 a series of open rock fissures and topographical depressions form a large arcuate scarp which suggest NLD 3632 is part of a much larger landslide complex. The fissures coincide with the scarps recorded on the topographical maps, indicating it was present in 1877-78.
- 4.41 In addition, a series of small depressions possibly representing landslide scarps were identified above the A4107 in the northwest to west part of the site. These depressions may also be related to coal mining, and be former adits accessing coal seams in the hill.
- 4.42 As outlined above, the landslides recorded on site are anticipated to be within the Rhondda Member, typically sandstone beds. The Rhondda Member is susceptible to instability due to a complex set of discontinuities which is observed as a major cause of valley instability throughout the South Wales coal field. Furthermore, thin mudstone beds within the Rhondda Member and Llynfi Member provide preferential groundwater paths which can lead to weathering and softening of the strata. Under the right conditions, these weak beds can form a plane of weakness resulting in massive failure. (Woodland, 1985).

Recorded Landslide – Off Site

- 4.43 Further landslides are recorded in the geological mapping north of the site in Cymmer and within the valley to the north.
- 4.44 In addition, a further three possible landslides were identified from the API to the southwest of the site.
- 4.45 One possible landslide feature is located on the southwest facing slope immediately to the south of the Foel Fawr. This comprises a southwest trending depression approximately 120m long and 110m wide.
- 4.46 The second possible landslide feature is located on the southwest facing slope 550m west of the Foel Fawr. This comprises a southwest trending depression approximately 120m long and 50m wide.
- 4.47 The third possible landslide feature is identified from a series of arcuate fissures in agricultural fields above Duffryn approximately 1.6km west of Foel Fawr.

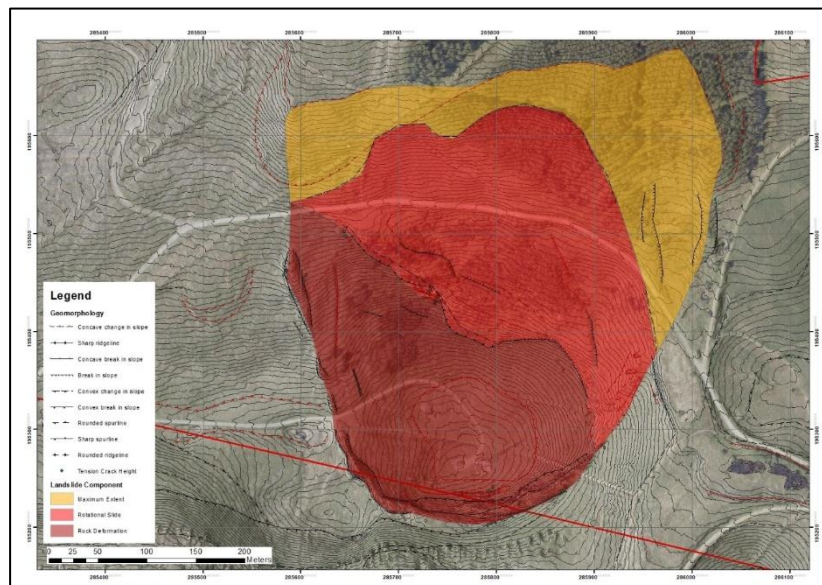
Landslide Assessment

- 4.48 The site was visited by two engineering geologists to undertake engineering geomorphological mapping. The mapping was based on field observations, the API derivative datasets from the DEM (in particular hillshade and slope angle).

- 4.49 The engineering geomorphological mapping is primarily based on morphological mapping (i.e., the “shape” of the landscape) interpreted to reflect geomorphological processes, both relict and active, and engineering geological materials. The focus of the mapping was on landslide processes both active and relict. The findings of the mapping are displayed on Figure 8a. Photographs from the mapping are included as inserts throughout this section, the locations where the photographs were taken are displayed on Figure 8b.
- 4.50 The mapping was based on the approaches described in Anon (1972), Anon (1982) and Brunsten & Griffiths (2001).
- 4.51 The engineering geomorphological map and landslide inventory map were developed by means of direct mapping. Jones & Lee (1994) define direct mapping as, *“involving the analysis of landforms and identification of existing landslides so that areas of past instability can be identified, thereby facilitating extrapolation from areas of recognized past instability to similar situations which may suffer slope failure in the future.”* According to Soeters & Van Westen (1996), this is an *“experience driven applied geomorphic approach, by which the earth scientist evaluated directly relationships between landslides and their geomorphic and geological settings by employing direct observations during a survey.”*
- 4.52 In general, the LiDAR review, aerial photograph interpretation (API) and geomorphological mapping identified a central landslide complex and two additional landslides within the vicinity of the site. The central landslide complex and landslide in the northwest generally correlate with BGS mapped landslides. The location of the landslides is displayed on Figure 8a and are discussed in detail in the sections below.

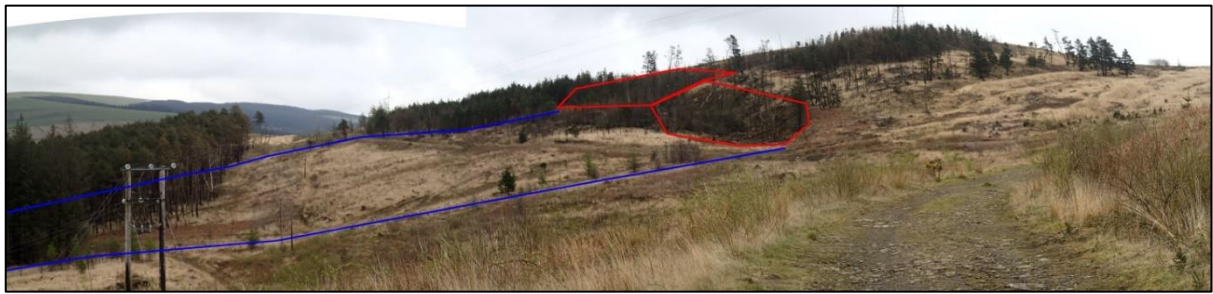
Central Landslide Complex

- 4.53 A landslide complex has been identified in the central portion of the site which broadly corresponds to the previous mapped BGS landslide (Ref. AA-17). The landslide complex has been interpreted as comprising three separate components (Insert 5).



Insert 5: Central Landslide Complex

- 4.54 **Landslide 1:** This broadly coincides BGS mapped landslide AA-17. It comprises a rotational landslide with a northwest-southeast trending main scarp (Insert 6) and associated debris. To the rear of the main scarp are two fissures (Insert 7) extending into rock. The height of the fissures at the main scarp measured between 1.0m and 4.0m. Joints within the exposed scarp were measured as dipping between 20 and 22° towards the northwest and southeast.
- 4.55 The LiDAR review and API identified these fissures which coincide with the scarps recorded on the topographical maps, indicating they were present in 1877-78.
- 4.56 The landslide was observed as being degraded with no significant evidence to indicate recent movement identified. The mapped toe of the landslide may be less visible/degraded due to anthropogenic influences (forestry and other man activities). The approximate mapped toe of the landslide is indicated below in blue, however the geomorphological mapping indicates the toe to extent downslope (north) within the forested area.



Insert 6: Rotational landslide. Approximate locations of Main Scarp (Red) and Toe (Blue) (Photo P1)



Insert 7: Fissure above Main Scarp of Rotational Landslide (Photo P2)

- 4.57 **Landslide 2:** Observed as rock deformation, this is most pronounced immediately south of Foel Fawr

with an arcuate scarp feature (Insert 8). Its surface expression varies from fissures in rock to linear topographical depressions (Insert 9) with no associated rock outcrop. These have been interpreted as defining the upper most extent of the landslide complex.

- 4.58 No mappable geological units were crossing within the rock fissures associated with the upper arcuate scarp, so the actual sense and scale of displacement was not measurable. The dip of the bedding varied from 3° to 22° and the direction from 224 to 354. The regional dip is shown on the geological map as being 10° to north-northwest. Rock measurements are displayed on Figure 8b.



Insert 8: 12m High rock scarp with dilated rock mass associated rock fall, west end of main scarp. (Photo P3)



Insert 9: Interpreted lowest extent of landslide complex, right flank, 3m to 4m scarp very degraded. (Photo P4)

- 4.59 It is considered that this forms a large deeper translational landslide likely associated with slip planes at depth where seatearth and mudstones may be present.

- 4.60 **Maximum Extent of Landslide Complex:** this is interpreted from relatively subdued geomorphological features evident in the LiDAR data alone and therefore has a higher degree of uncertainty to it. The API did not identify significant evidence of the landslide maximum extents.
- 4.61 There is a possibility that the landslide complex extends further north, perhaps off site, resulting in a large landslide effecting much of the central portion of the site. The morphology of the northern boundary of the site does not suggest a lobate structure or expression of such a large landslide and has thus been generally disregarded but it is a possibility. Ground investigation should confirm the bedrock ground model and other positions should attempt to prove the mapped toe of the landslide.

Additional Landslides

- 4.62 **Northwest Landslide** BGS mapped landslide AA-18 in the northwest portion was inspected. Whilst a broad lobate feature (insert 10) is present within the central portion of the feature, there was no conclusive evidence from the geomorphology that this comprises a landslide. However, the road cutting through the toe of the feature suggest the lobe comprises angular cobbles and boulders of sandstone in cohesive matrix. This contrasts with the colluvium noted in slope cuttings within the site which typically comprises soft to firm silty clay with much medium to coarse angular gravel and cobbles of sandstone.



Insert 10: Lobate feature associated with NLD Feature 3633 (Photo P5)

- 4.63 This possible landslide in the northwest should be investigated further to allow an updated assessment to be completed. We have provided recommendations for its investigation which will allow for this updated assessment and will also provide ground conditions for future road design in this area.
- 4.64 **Southern Landslides:** Two possible landslides to the south of the site were inspected and only the one 550m to the east of Foel Fawr was confirmed as a landslide. This appears to be a relatively shallow earth flow which probably reactivates during periods of significant rainfall, estimated to be every year to every 10 years. The earthflow is probably related to the weathering of the clay rich Llynfi Member.
- 4.65 **Rock Fall:** Rock outcrops are associated with the northwest trending ridge line in the north of the site, and these have generated rockfall (Insert 11). These appear to be relatively infrequent, probably occurring every 10 to 100 years. No evidence of recent rockfall, e.g., recent ground disturbance, was observed.



Insert 11: Rock outcrops and associated rock fall (Photo P6).

- 4.66 **Cymmer Landslide:** Based on the API and field observations there is no evidence of the BGS mapped landslide in Cymmer north of the site. The reasons as to why this was recorded on the geological mapping are unclear. The feature is located beneath the village of Cymmer and there was no obvious evidence of any structural distress associated with the buildings in the village. ESP have made enquired to the BGS who have confirmed that no original field records are available for the mapping.

Other features

- 4.67 The incised drainage lines observed in the API were inspected and there was no evidence of instability associated with them.

Landslide Hazard Types

- 4.68 Based on a combination of API, field mapping and knowledge and experience, two possible hazard types have been identified (Figure 8a):

- Hazard Type 1. Rock fall initiating from intermittent outcrops above the proposed access road; and
- Hazard Type 2. Reactivation of the large complex landslide.

Hazard Type 1

- 4.69 Rock fall initiating from the intermittent rock. Movement velocities of such rock falls are likely to be very rapid (5×10^1 mm/s to 5×10^3 mm/s i.e., 3m/min to 5m/sec). If rock falls reach the access road these could potentially result in a risk to life.

Hazard Type 2

- 4.70 Reactivation of the large landside complex. Associate movements are likely to be very slow to slow (5×10^{-7} mm/s to 5×10^{-5} mm/s i.e., 1.6m/year to 16mm/year). Given the low movement velocities these are unlikely to pose a risk to life but could result in the deformation of any constructed structures.

Landside Hazard Assessment

- 4.71 When estimating the probability of a landslide occurring there are two fundamentally different approaches; the frequentist and the degree of belief (Lee and Jones 2014). The frequentist approach involves the statistical analysis of an inventory of landslide events in a particular area over time. In comparison, the degree of belief involves making a judgement based on available information and experience. Given the lack of a comprehensive landslide inventory, this assessment is a combination of both approaches.
- 4.72 Landslide hazard comprises two distinct components, the probability of a landslide occurring and the probability that the detached material will impact of the elements at risk.

Hazard Type 1 - Rock fall initiating from the intermittent rock outcrops the main scarp.

- 4.73 The likelihood is considered to be relatively low with an assumed probability of detachment of 10s to 100s of years adopted.
- 4.74 The Concept Master Plan dated April 2017 shows the access road being located on the southern side of the valley, i.e., opposite the location of the rock fall debris. The existing slope is vegetated and the likelihood of a rock blocks reaching the road has been provisionally estimated with a probability of 0.1. This suggests a likelihood of impact on the road of between 100 and 1000 years (0.02 to 0.02) (low to very low hazard AGS, 2007) without any mitigation works being undertaken.

Hazard Type 2 - Reactivation of the large complex landslide.

- 4.75 Whilst there is clear evidence of previous ground movement there is no evidence from the historical topographical maps (1877) or aerial photograph interpretation (1947) of any historical movement. It is postulated that the movement occurred at the end of the last glaciation approximately 10,000 years ago associated with conditions that no longer exist today or are unlikely to occur again in the near future. As such the landslide complex is considered to be relict (Cruden and Varnes, 1996).
- 4.76 The Concept Master Plan dated April 2017 shows the hotel and spa, ski lift and apartments being located within the rotational slide component of the complex landslide, with lodges proposed within the estimated maximum extent sone of the landslide and extending into the rock deformation zone.
- 4.77 If extensive site formation works are undertaken there is the possibility of reactivating the rotational slide component of the large complex landslide. However, the probability of this is uncertain given the limited information available at this time. If it is simply assumed that the likelihood of occurrence of the rotational component of the landladies is 1×10^{-4} (based on it occurring at least 10,000 years ago) and that site works could reduce this by an order of magnitude, i.e., 1×10^{-3} this would equate to a “moderate” hazard (AGS, 2007).
- 4.78 In order to provide an initial estimate of the likelihood of risk to the project, the AGS qualitative approach (Appendix H) for risk to property has been adopted. An approximate annual probability of movement of 1×10^{-3} is considered as an event “which could occur under adverse conditions over the design life” with a qualitative descriptor of “possible”.

- 4.79 Given the nature of the hazard it has been assumed that reactivation could result in damage costing between 10% and 100% of the build costs, varying from “extensive damage to most of the structures requiring significant stabilisation works” to “moderate damage requiring large stabilisation works”, with consequence descriptions varying from “medium” to “major”.
- 4.80 Likelihood of “possible” combined with consequence varying from “major” to “medium” indicate risk levels varying from moderate to high. AGS (2007) gives example implications of these levels of risk as:
- Moderate Risk – “May be tolerated in certain circumstances (subject to the regulators’ approval) but requires investigation, planning and implementation of treatment options to reduce risk to Low”.
 - High Risk – “Unacceptable without treatment. Detailed investigation, planning and implementation or treatment options to reduce risk to Low.

Landslide Conclusions

- 4.81 Two landslide hazard types have been identified in the site boundary:
- Rock fall associated with the access road.
 - A landslide complex located in the central portion.
- 4.82 The rockfall hazard is likely to be relatively straight forward to manage, with the risk being reduced by either road realignment or mitigation measures such as rock scaling or the installation of a rock fall berm.
- 4.83 The landslide complex is more problematical as there is currently no information on the landslide geometry nor on the geotechnical properties of the material associated with it. Based on this preliminary study, the potential risk to any structures located within it are considered to moderate too high. The easiest way to reduce this risk is to locate any proposed facilities outside the landslide footprint. However, based on the current site layout this would have a significant impact to the proposed development. Consequently, further investigation, including detailed mapping and ground investigation will be necessary to allow a more detailed examination of both the hazard and risk associated with this feature.

Landslide Assessment Uncertainties

- 4.84 There is no site-specific ground investigation, and the assessment of landslide hazard has been based entirely on a desk study and limited reconnaissance mapping. Consequently, the assessment of the probability of detachment and run out used in the assessment are based on expert judgment. As such, there is a relatively large degree of uncertainty associated with them. However, this initial assessment provides a starting point for a more detailed assessment of landslide hazard and risk should the site proceed.

FAULTS

- 4.85 A number of north to south trending normal faults are mapped across the site.
Pen-y-Castell Fault
- 4.86 In the western extent the Pen-y-Castell Fault is indicated, the recent BGS (2022) mapped location is displayed on Figure 3. The 1:10,000 geological mapping indicates a similar alignment.

- 4.87 The Coal Authority Consultants mining report (CA, 2022) (Appendix Fi) indicates the fault alignment to be in keeping with the BGS mapped location, though slight variation is noted.
- 4.88 Abandonment plans obtained from the Coal Authority (Ref. 9475) plot the fault line to be further west than the BGS and CA mapped alignment however, this may be a result of the fault plane dipping to the west and therefore the fault is expressed to the west at depth.
- 4.89 An initial LiDAR review indicated a possible surface expression of the southern extent of the fault, where a morphological change was noted immediately south of the southern site boundary and partially extending into the site, as shown on Figure 6. This southern expression lies to the west of the BGS mapped fault and is more in keeping with the CA (2022) and abandonment plan (Ref.9475) placement.
- 4.90 Towards the north, a less apparent possible surface expression of the fault is noted (see Figure 6), this lies significantly further west than the mapped fault location (BGS and CA), however is closer to the abandonment plan location. No significant evidence of the fault was noted from the API.
- 4.91 The possible alternative alignment is indicated on Figure 9 however, this location is to be further delineated with intrusive ground investigation works.

Eastern Normal Faults

- 4.92 Two normal faults are mapped (BGS, 2022) trending north to south with down through to the east and west. A third fault is mapped trending northwest to southeast.
- 4.93 No significant evidence of a surface expression of the most easterly north to south fault in the eastern extent of the site was noted during the API, LiDAR review or from site observations. The exact location of this fault is to be further investigated with intrusive site investigation works.
- 4.94 Surface expressions in the form of morphological changes and fissures likely denote the more western fault, downthrown to the west and the northwest to southeast trending fault as observed on site and the LiDAR and API review. The northwest to southeast fault follows a similar trend to the backscarp of the BGS mapped landslide (LS1).

Possible Unmapped Faults

- 4.95 In the southeastern portion of the site, a scarp/fissure feature was recorded on site and in the LiDAR and API review. The feature is considered to delineate the southwestern extent of landslide 2 (LS2) and may represent an unmapped fault.
- 4.96 Intrusive site investigation works have been undertaken by Stantec (2022) with regards to other possible faults on site (including not previously mapped faults), the results of which will be discussed as part of the interpretative site investigation report following completion of works on site.
- 4.97 Review of the Abandonment plans indicate numerous faults within the working with a varying degree of offset and length.

COAL MINING

Previous Assessment

- 4.98 A Coal Mining Risk Assessment (CMRA) for the site has been carried out by Aecom (2017) and the information provided as part of this assessment has been reviewed by ESP. It should be noted that the assessment identified variation between the names of coal seams between various sources including BGS geological records and Coal Authority Abandonment Plans. Alternative coal seams names are included in brackets.
- 4.99 A factual summary of the findings of the CMRA (Aecom, 2017) is provided below:
- A CON29 Mining Report obtained by Aecom (CA, 2017) for the site indicates the presence of 13no. workable seams at variable depths below the site (surface outcrop to 260m depth).
 - 4no. mine entries are recorded within or within 20m of the site boundary including three shafts and one adit. The adit is recorded as being reinstated with stone in 1977. It is understood a 30m (diameter) development exclusion zone has currently been applied by the Coal Authority.
 - Mine abandonment plan records have been obtained for the site which indicate extensive underground coal mining. A record for the Glyncymmer Colliery shows workings below the site of the No.2 Rhondda and Wernpistyll Rider coal seams between 35m to 122m and 32m to 84m depth respectively. A record for the Duffryn Rhondda Colliery shows workings of the Field Seam (Field Vane) and Wernddu (No. 2 Rhondda) in the western extent.
 - For the purpose of the assessment, the site was divided in 3 zones (A to C) primarily defined by structural faulting on site.
 - Coal mining in Zone B is considered to be within influencing depth of the ground surface:
 - **Zone B:** No.2 Rhondda (Field Vein and Wernddu) and Wernpistyll coal seams (<30m) and Unnamed Seam (C) (White) and Tormynydd.
 - Numerous shallow and dominant coal seams are shown across the site with no records of historic workings but may have actually been worked. Other less economically or spatially insignificant coal seams exist which may have been worked historically.
 - The abandoned Cymmer Railway Tunnel exists beneath the central portion of the site trending north to south. The tunnel is constructed of stone with brick insert. Though ventilation shafts are not anticipated due to the depth, their presence cannot be discounted.
 - The report includes the following comments on coal mining induced instability: 'According to BGS Geological Mapping, there exist at least two landslides at the site... these are believed to be examples coal mining-induced slope instability (i.e., failure arising from collapse or void migration at depth triggering slope stability). A large landslide is present at the crest of the hillslope, where the antenna is located (to south of site). This instability feature shows considerable vertical but only a small amount of lateral displacement. The instability is likely associated with coal seam exploitation at the Glyncymmer Colliery.'

Updated ESP Coal Mining Risk Assessment

- 4.100 Following receipt of a Consultants Coal Mining Report, an updated Coal Mining Risk Assessment has been undertaken by ESP. As part of the assessment, updated mining abandonment plans for records held beneath the site have been obtained by ESP alongside mine entry data plans. Abandonment plans up to a depth of 300m only have been reviewed as part of this assessment and these are discussed further in the sections below.
- 4.101 The site is underlain by bedrock of the Pennant Sandstone Formation, which contains several seams of coal. For the purpose of this updated assessment, the site has been zoned as the Western, Central and Eastern extents.
- 4.102 A coal mining setting for each zone is provided below and is based on geological mapping (both 1:50,000 and 1:10,000 scale geological mapping) and information obtained from the Coal Authority website (CA, 2022). It should be noted that the dip of the bedrock is towards the north and therefore each of the seams discussed below are anticipated to underlie the site. The coal mining setting of the site is displayed as Figure 9.

Western Area Setting

- 4.103 West of the Pen Y Castell Fault, the conjectural outcrops of three coal seams are shown to cross the site trending north - south and then east – west is indicated on the 1:10,000 geological mapping. Reference to geological mapping indicates these are the Brithdir Coal seam in the north, the No. 1 Rhondda Rider in the southern extent (see Figure 3) and a thin coal seam below the No. 1 Rhondda Rider. The bedrock and coal seams are the youngest in the stratigraphical succession at the site as a result of the significant downthrow of the Pen y Castell Fault (approximately 180m to the west).
- 4.104 A set of possible adits were noted in the western extent which are initially considered to have worked the No. 1 Rhondda Rider shown to outcrop in the area as indicated on Figure 6
- 4.105 In addition to the above, the Coal Authority website (CA, 2022) indicates that in the western portion of the site;
- No recorded or probable past shallow coal mining is recorded.
 - No past surface hazard or surface mining is identified.
 - No mine entries are shown.
 - Where coal outcrops are shown, the immediate vicinity is indicated to be a 'Development High Risk Area'.

Central Area Setting

- 4.106 In the central area, comprising the land east of the Pen Y Castell Fault, four coal seams are indicated to outcrop. Coal seams interpreted as the No.1 Rhondda Rider and No. 1 Rhondda are shown in the north of the central area. The No. 2 Rhondda, comprising the leafed Field Vein and Wernddu coal seam, is indicated trending east – west, south of the site and partially encroaching the site boundary in the southeast extent. The Wernpistyll coal seam and further thin coals are shown south of the site.
- 4.107 In the southeastern extent, the coal outcrops are shown to be deformed and displaced by normal faulting, it is likely that this was discovered as a results of mine working in the area. In this area, between the two normal faults, the conjectural outcrop of the Wernpistyll coal seam is shown on site, trending east – west.
- 4.108 As discussed above, based on the dip of the bedrock, these coal seams are anticipated to underlie

the site. Though not mapped, the Wernpistyll Rider is indicated in the stratigraphic column and is also anticipated to be present beneath the site.

- 4.109 In addition to the above, the Coal Authority website (CA, 2022) indicates that in the central portion of the site;
- Past shallow coal mine workings are recorded in the southern and northern extent of the central area.
 - No past surface hazard or surface mining is identified.
 - 4no. mine entries are shown within the central area with 1no. shown immediately north of the site boundary.
 - Where coal outcrops and past shallow workings are shown, the immediate vicinity is indicated to be a 'Development High Risk Area'.
- 4.110 A review of LiDAR data and subsequent geomorphological mapping has identified the presence of a line of adits immediately south of the site. The adits are considered to have been used for extractions of the extensively worked No. 2 Rhondda, with the two levels of adits representative of both the Field Vein and Wernddu coal seams. The line of adits is noted to terminated in the west broadly in-line with the mapped location of the Pen Y Castell Fault.

Eastern Area Setting

- 4.111 The eastern area comprised the land to the east of the unnamed fault trending north to south in the eastern site extent (see Figure 3). The downthrow of the eastern fault is considered to be relatively low (<10m to the east). The No. 2 Rhondda, comprising the leafed Field Vein and Wernddu coal seam, is indicated trending east – west then north - south (following topography) along the site boundary. The Wernpistyll coal seam and further thin coals are shown beyond south of the site.
- 4.112 As above, based on the dip of the bedrock, these coal seams are anticipated to underlie the site. Though not mapped, the Wernpistyll Rider is indicated in the 1:10,000 mapping stratigraphic column and is also anticipated to be present.
- 4.113 In addition to the above, the Coal Authority website (CA, 2022) indicates that in the eastern portion:
- No recorded or probable past shallow coal mining is recorded.
 - No past surface hazard or surface mining is identified.
 - No mine entries are shown within the boundary though one mine entry is shown immediately south east.
 - Where coal outcrops are shown, the immediate vicinity is indicated to be a 'Development High Risk Area'.

Coal Authority Consultants Mining Report

- 4.114 A consultant's mining report has also been obtained from the Coal Authority and is presented in Appendix F. This indicates that, based on the available Coal Authority records:
- There are 60no. records of workings of coal beneath the site, at depths of between 0 and 786m. The workings are recorded for 11no. named coal seams and 4no. unnamed seams. No colliery details are provided.

- The shallowest workings were within an Unnamed coal seam and No.2 Rhondda seam at 0m (ground level). The extraction thicknesses are reported as 0.57m and 0.91m respectively.
- Further records within the Unnamed coal seam and No.2 Rhondda seam are held within 250m depth with a maximum extraction thickness of 1.0m recorded in the No. 2 Rhondda at 38m depth.
- Seven records are held for spine roadways at shallow depths beneath the site. No further information is provided – see below for further discussion.
- There are 6no mine recorded entries within 100m of the site – see below for further discussion.
- Abandoned mine plan records are available which may intersect with some or all of the enquiry boundary – see below for further discussion.
- There are 4no recorded geological faults beneath the site (in keeping with geological mapping). There are no fissures recorded beneath the site.
- There are no recorded damage notices or claims for the subject property, or any property within 50m of the site boundary, since 31st October 1994.
- There is no record of any request having been made to carry out preventive works before coal is worked under section 33 of the Coal Mining Subsidence Act 1991.
- One record of mine gas emission is recorded at 210.9m west of the site. The site is in an area of previous interest for mine gas remedial works – see below for further discussion.
- There is no proposed future mining or licensing proposed.
- No notices have been given under Section 46 of the Coal Mining Subsidence Act 1991 stating that the land is at risk of subsidence.
- The site located in an area of historical coal mining activity.

4.115 The report recommends that a Coal Authority Mine Gas Emission Report is obtained.

Mine Entries

4.116 A summary of mine entries recorded within 100m of the enquiry boundary is provided in Table 1 below. All mine entries are for coal extraction. Mine Entry Data Plans (CA, 2022) were obtained with salient information included within Table 9 overleaf. The full records are displayed in Appendix F.

Table 9: Summary of Mine Entries

Entry Reference	Type	National Grid Reference	Treatment Description	Additional Information	Site Area ³
285195-004	Shaft	285638 195884	This shaft was filled with stone in 1977 and the surface reinstated.	Listed as Old Air Shaft.	Central Area (N)
285195-005	Adit	285663 195956	Unknown.		Off-site (30m N)
285195-007	Adit	285484 195761	Unknown.	Listed as Old Trial Level.	Central Area (N)
285195-009	Shaft	285981 195719	Unknown.		Central Area (NE)
285195-010	Shaft	285985 195663	Unknown.		Central Area (NE)
286195-003	Adit	286592 195400	Unknown.	Listed as Old Trial Level.	Off site (65m SE)
Notes:					

1. Mine entries are as recorded in the Consultants Mining Report (Appendix F).
2. Entry Ref. 285195-004 is indicated to be an air shaft on historical mapping.
3. Distance from site boundary is approximate only.

- 4.117 Given the available information, we consider that the most of mine entries are likely to have been constructed to access workings within the No. 2 Rhondda coal seam. Mine entry (adit) 285195-007 is likely to have worked the No. 1 Rhondda in the central portion.
- 4.118 The Coal Authority report (2022) does not note the presence of the adits identified south of the site boundary which are considered to have worked the No. 2 Rhondda coal seam (Field Vein and Wernddu).
- 4.119 As discussed above, a set of possible adits is noted in the western extent (see Figure 6) which are initially considered to have worked the No. 1 Rhondda Rider shown to outcrop in the area.

Mine Abandonment Plans

- 4.120 Abandonment plans (showing the extent of workings at the time of their abandonment) for workings beneath the site up to a depth of 300m have been obtained by ESP from the Coal Authority (2022). The full records are displayed in Appendix F iii.
- 4.121 Further abandonment plans from recorded workings at greater depth have been obtained at the request of the Client however, at this stage we consider these workings to be at a such a depth that they should not pose significant risk to the proposed development however, this should be reviewed following the preliminary site investigation works.
- 4.122 It should be appreciated that the Coal Authority records are known to be incomplete, partly because there was no statutory and mandatory requirement on colliery owners to survey and submit records of the extent of their mine workings to the Secretary of State until the Coal Mine Regulation Act of 1872. Therefore, given the potential age of the workings, the actual extent of mine workings may extend further than shown on the abandonment plans. It should be appreciated that all coal reserves, including abandoned workings are under the ownership of the Coal and their permission must be obtained before any investigation can be undertaken to intercept these features.

Table 10: Summary of Mine Abandonment Plans for recorded workings beneath the site (up to 300m depth).

Catalogue No.	Principle Seam Name	Local Seam Name
9475	Unnamed	Wernpistyll
9475	No.2 Rhondda	
SWA778	No.2 Rhondda	
10304 (2)	Eighteen Inch	Two and a half ft seam

4.123 Catalogue No. 9475 - Glyncymmer Colliery

The record indicates two areas of former mine workings, with the area south of the River Afan recording workings beneath the site. The plan records workings within the No. 2 Rhondda Seam between approximately 35mbgl and 122mbgl, and the Wernpistyll Rider between approximately

32mbgl and 84mbgl. The workings are recorded predominantly in the western and north eastern extent of the site.

Within the workings beneath the site, the Wernpistyll Rider coal seam is recorded as a thickness of 1ft5in., and the No.2 Rhondda is recorded at 2ft6in. The plan records a number of north to south trending normal faults in the northern extent of the site which are not recorded on the geological mapping. The faults are recorded with downthrows of between approximately 0.9 and 5.5m, towards to the east and west.

4.124 **Catalogue No. SWA778 - Duffryn Rhondda/Drift/Drainage Adit**

The plan produced in 1966 records workings within the No.2 Rhondda at the Duffryn Rhondda Colliery. The plan records a drift mining region access via an adit and deep underground mining access via two shafts (No.1 Shaft and No.2 Shaft). The shafts and adit are recorded approximately 350m west of the site boundary. The mined region extends north to south across the western extent of the site (longwalls orientated east-west), the depths of the chambers gradually increase in depth towards the north. The plan includes hydrogeological records including limit of water, pump flow rates and free draining water to the River Avan.

4.125 **Catalogue No. SWA3179 - Duffryn Rhondda/Cynon**

The plan produced in 1966 records workings within the Eighteen Inch (2 ½ Foot) at the Duffryn Rhondda Colliery approximately 400m west of the site. The mining region and shaft locations are as recorded in Catalogue SWA778. The depth of the shafts are recorded as approximately 730mbgl with workings recorded within the Eighteen Inch at approximately 460mbgl, becoming shallower to the south and deeper towards the north of the shafts.

4.126 **Catalogue No. 10304 - Caerau No.3**

The plan produced in 1930 records workings within the Eighteen Inch (2 ½ Foot) at the Caerau No.3 colliery at approximately 250m depth. The plan records workings outside of the site boundary to the southwest. It should be noted that unrecorded workings may extent to within the site boundary footprint.

Discussion

4.127 The Coal Authority indicate recorded workings within an Unnamed coal seam (Wernpistyll Rider) and the No. 2 Rhondda seam at a depth of between 0 and 60m beneath the site. Further workings within the No. 2 Rhondda coal seam are indicated between 202 and 224m depth beneath the site. The coal seams expected beneath the site and their anticipated working depth is present below in Table 11. The following summary should be updated following receipt of updated Coal Authority abandonment plans and exploratory ground investigation works.

Table 11: Summary of anticipated coal seams

Coal Seam		Reported Thickness	Anticipated Seam Depth (approx.) ¹	Worked	Colliery	Method
Western Area						
Brithdir		Thin	0 - <10m	Unknown	-	-
No.1 Rhondda Rider		1 ft 6 in (0.45m)	0 – 50m	Unknown	-	-
No.1 Rhondda		0 – 2ft (0 – 0.6m)	40 – 90m	Unknown	-	-
No. 2 Rhondda	Field Vein (leafed)	2ft 3in (0.68m)	130 – 180m	Yes	Duffryn Rhondda Colliery	Longwall Mining
	Wernddu	3ft (0.9m)	145 – 195m	Yes	Duffryn Rhondda Colliery	Longwall Mining
Wernpistyll Rider		1 ft 6 in (0.45m)	155 – 210m	Unknown	-	-
Wernpistyll		1 ft 6 in (0.45m)	165 – 220m	Unknown	-	-

Table 12 Cont.: Summary of anticipated coal seams

Central Area						
No.1 Rhondda Rider	1 ft 6 in (0.45m)	0 – 10m	Unknown	-	-	
No.1 Rhondda	0 – 2ft (0 – 0.6m)	0 – 50m	Unknown	-	-	
No. 2 Rhondda	Field (leafed)	2ft 3in (0.68m) 0 – 50m	Yes	Glyncymmer Colliery	Pillar and stall	
	Wernddu	3ft (0.9m) 0 – 60m	Yes	Glyncymmer Colliery	Pillar and stall	
Wernpistyll Rider	1 ft 6 in (0.45m)	20 – 50m	Unknown	-	-	
Wernpistyll	1 ft 6 in (0.45m)	30 – 65m	Unknown	-	-	
Thin Coal	Thin	60 – 100m	Unknown	-	-	
Thin Coal	Thin	80 – 120m	Unknown	-	-	
Tormynydd	Thin	150 – 190m	Unknown	-	-	
Eastern Area						
No. 2 Rhondda	Field (leafed)	2ft 3in (0.68m) 0 – 45m	Yes	Glyncymmer Colliery	Pillar and Stall	
	Wernddu	3ft (0.9m) 0 – 60m	Yes	Glyncymmer Colliery	Pillar and Stall	
Wernpistyll Rider	1 ft 6 inn(0.45m)	0 – 65m	Unknown			
Wernpistyll	1 ft 6 in (0.45m)	15 – 70m	Unknown			
Thin Coal	Thin	40 – 105m	Unknown	-	-	
Thin Coal	Thin	80 – 145m	Unknown	-	-	
Notes:						
1. Approximate coal seam depth range based on bedrock dip of 10° north. Depths to coal seams to be confirmed with intrusive ground investigation methods.						

4.128 Based on the available information we consider that potential former underground coal workings may be present as below:

Western Area

The No. 1 Rhondda and No.1 Rhondda Rider outcrop in this area and possible adit features have been identified in the western extent, we consider it possible that shallow workings will be present in these coal seams. Workings in the No. 2 Rhondda are anticipated at depths >100m in this western area.

Central Area

The available information indicates that there are abandoned mine workings within the No. 2 Rhondda coal seam at between ground level and 40m depth (approx.) beneath the central area. Abandoned workings associated with the No. 1 Rhondda Rider and No. 1 Rhondda are considered likely in this area too, anticipated from ground level. Further workings associated Wernpistyll, Wernpistyll Rider and thin coals are anticipated possible at greater depths.

Eastern Area

In the eastern area, though not recorded, workings within the No.2 Rhondda coal seam are anticipated between ground level and 60m in the south eastern extent. Further workings within the Wernpistyll and Wernpistyll Rider are considered possible at between ground level and 70m depth. An adit is indicated off site which is likely to access to the No.2 Rhondda coal seam. Enquires are ongoing with the Coal Authority with regards to coal workings in this area.

Coal Mining Hazards

- 4.129 Figure 11 shows the potential high risk subsidence zones for each of the coal seams that are anticipated to underlie the site. These zones are based upon 10T at this preliminary stage, with T being assuming seam thickness.
- 4.130 A potential subsidence hazard zone is shown on Figure 11 that is present across the entire site. The coal seams below the site have been exploited and natural variation, faulting, folding may alter the ground model and shallow subsidence zones are possible. The zone also highlights that mine shafts may be present on the site that have not been recorded or identified.
- 4.131 Mine entries are shown and present a hazard of collapse, which may be larger than their plan area. There may be unrecorded entries across the site not identified by this assessment.
- 4.132 The ground model needs to be confirmed through investigation and this should enable the coal mining hazards to be understood fully, which will allow refinement of Figure 11 subsidence hazard zones.

FURTHER COAL MINING CONSIDERATIONS

Pillar and Stall Mining

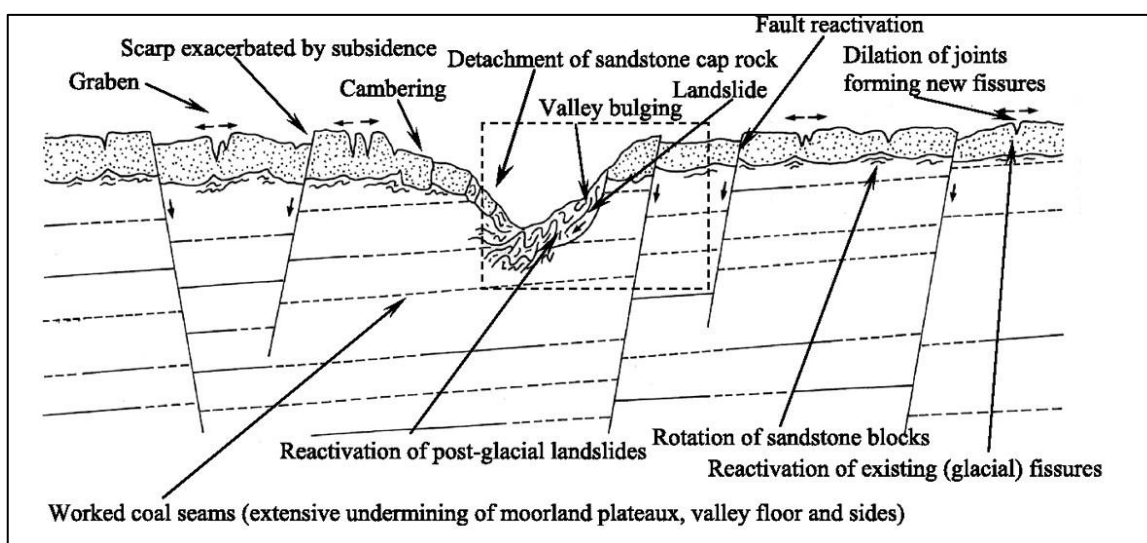
- 4.133 The Coal Authority abandonment plans indicate that the mine workings in the central portion of the site (east of the Pen Y Castell fault) were carried out using the pillar and stall method, whereby the coal is partially extracted using regular supporting pillars. The workings in this area (ref. [9475](#)) are understood to have extracted the No.2 Rhondda coal seam.
- 4.134 During retreat and abandonment of the workings, the pillars were often ‘robbed’ of material therefore reducing their strength leading to the potential for collapse. Collapse of the pillars and roof structure may subsequently lead to void migration and subsidence at the ground surface.

Longwall Mining

- 4.135 Based on the mine abandonment plans obtained from the Coal Authority (CA, 2022), we consider that the mining patterns displayed in the plan for Duffryn Rhondda/Unnamed Adits & Fan House (ref. SWR3776) are indicative of longwall mining techniques within the No. 2 Rhondda coal seam.
- 4.136 Longwall mining methods were more widely adopted in the mid 1900’s and allowed for almost completed removal of the target coal seam (as opposed to ‘pillar and stall’). Surface subsidence can be observed where longwall mining has occurred within workings at several hundred metres depth. Where longwall mining methods are adopted a ‘subsidence wave’ can be created at ground surface. Such subsidence generally occurs shortly after the extraction of coal (i.e., weeks/months). Though some amount of result of residual subsidence can continue to develop over a longer time period. Consideration is required for the potential for deterioration of previously support roadways long after longwall mining activity has ceased (CIRIA, 2019).
- 4.137 The amount of subsidence resulting from longwall workings is dependent on the worked area, depth of working and thickness of extraction. Previous information indicates that the approximate minimum depth of the longwall mine chamber was 150m below ground level.

Fault Reactivation

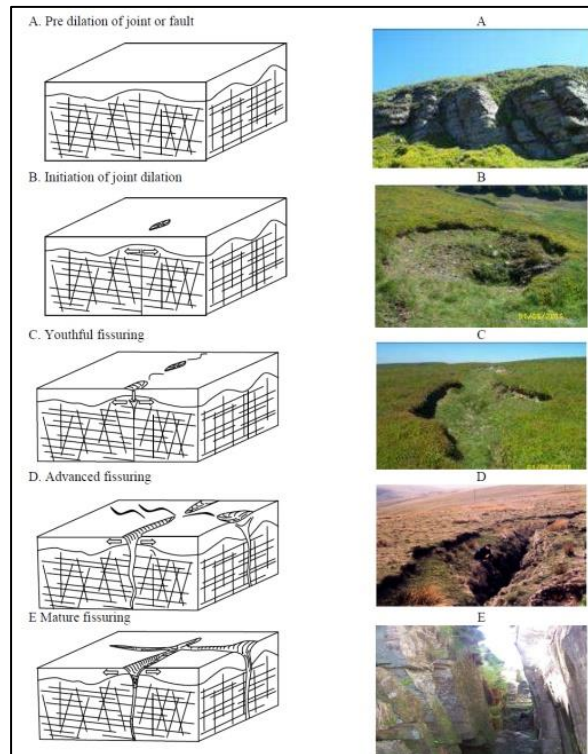
- 4.138 The geological mapping shows a number of north to south, normal structural faults crossing the site. A smaller fault is also shown in the southern area, on an orientation of northwest to southeast. Further possible unmapped faults have been identified on site.
- 4.139 Mining and mining subsidence can reactivate faults, and this can lead to surface depressions or subsidence (Insert 12). Fault reactivation occurs throughout the coalfields of Britain. Reactivated faults which are unequivocally induced by mining subsidence alone rarely exceed 0.5 to circa 1m in height (Donnelly, 2010).



Insert 12: Schematic illustration of coal mining subsidence-induced reactivation of faults on steep slopes and moorland plateaux, and their influence on the reactivation of ancient (probably post glacial) landslides (Donnelly, 2009)

POSSIBLE GRABEN ZONE

- 4.140 A series of fissures and possible grabens were observed in the southeast and eastern portion of the site. The features are recorded on earliest topographical maps (1877-78). They are similar to the arcuate main scarp in that they comprise rock fissures topographical depressions a typically orientated WNW and form an east-northeast trending zone of possible graben development.
- 4.141 Two ponds are located within this area are possible sag ponds. These are located in what are considered to be the most mature fissure, with the widest lateral spread.
- 4.142 The potential grabens were judged to vary in age, with fissures and grabens varying from 'initiation of joint dilation' to 'mature fissuring', as shown in Insert 13.
- 4.143 The mature possible grabens were noted to be around 5 to 6m in depth and appear to be more gradational in nature further to the east of the site. Youthful fissures were noted near to more mature possible graben features.



Insert 13: Schematic diagram to illustrate the evolution of fissures. Dilation of fissures in direction arrows may be strongly influenced by glacial stress relief and or mining. Donnelly 2010.

- 4.144 Figure 11 shows the visually identified potential graben zone (light purple shading) with the main associated fissures shown by dark purple lines. Graben like features have not been noted elsewhere on site and it is possible they are restricted to the east of the north-south mapped fault in this area, however this is an assumption. The eastern portion of the site, as defined by the eastern most north-south fault has been identified as a potential graben hazard zone, in that there may be other unrecorded, juvenile fissures and grabens in this area. Investigation should confirm the extent of the fissures and grabens across the whole site.

SUBSIDENCE

- 4.145 The stereo InSAR data has been reviewed and presented within Figures 7a (vertical movement) and 7b (horizontal movement). The data presented represents the vertical/horizontal position relative to the first image (dated 5th January 2017).
- 4.146 The InSAR data presented on Figures 7a and 7b is dated 8th February 2022, however for the purpose of this assessment, the full set of data was preliminarily interrogated.

Vertical

- 4.147 As indicated on Figure 7a, the greatest vertical displacement is identified in the western and southwestern portions where subsidence generally in the region of 20 – 30mm is recorded. Based on the information to date, we consider this may be associated with historic coal mining and faulting in this area of the site.

- 4.148 Further areas of high relative subsidence are noted in the central southern area downslope from the telecommunications mast. The subsidence is indicated to coincide with the mapped backscarp of the feature identified as Landslide 1.
- 4.149 In the area of the Graben Fault zone the data indicates relatively stable conditions with minor uplift and subsidence indicated in the southern most extent. No clear correlation has been observed between the mapped graben features and apparent vertical movement.

Horizontal

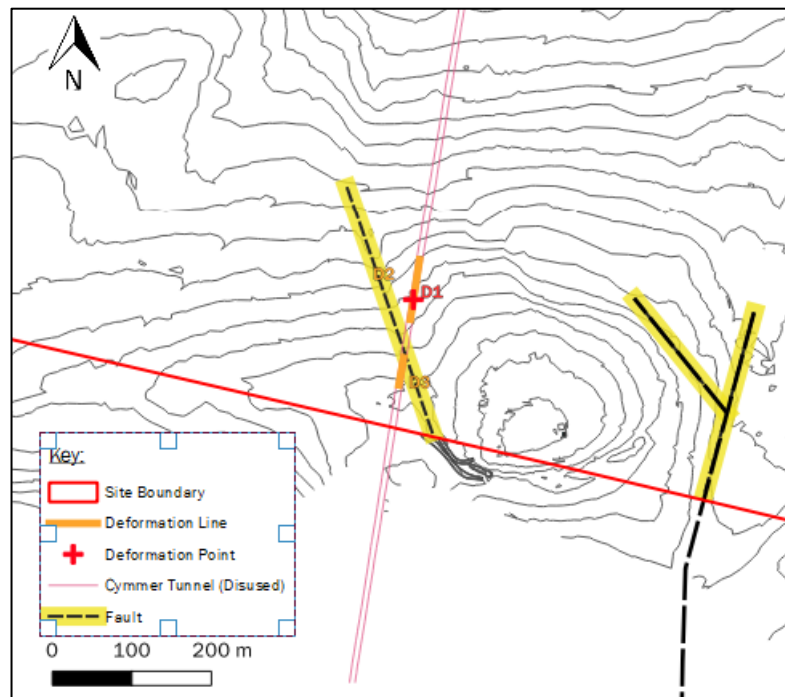
- 4.150 The horizontal displacement (east/west) is displayed on Figure 7b and generally indicates relatively stable conditions across the site. The area of most displacement, primarily to the east, is identified in the central portion though no significant correlation between previously identified features has been observed.

Limitations

- 4.151 As discussed above, a preliminary interrogation of the full data provided has been undertaken at this stage however, further detailed assessment is required. It is recommended that this be undertaken following exploratory ground investigation works and development of the detailed site ground model.

TUNNEL SURVEY

- 4.152 A Tunnel Visual Examination Report (Balfour Beatty Rail, 2020), has been provided to ESP from National Highways regarding the Cymmer Tunnel which passes under the site, the full records are displayed in Appendix J. The report indicates that the inspection was undertaken in February 2020 and includes photographs, records of the structural integrity of the tunnel and other salient information regarding the tunnel line (Bridgend to Abergwynfi). The report notes that at the time of inspection, track drainage maintenance and repairs works were in progress.
- 4.153 A review of the inspection record has indicated three areas of note where further assessment should be undertaken. The locations of the deformation relative to the mapped Cymmer Tunnel alignment is displayed as Insert 14:
- **Ref. Photo 35, 046+00 to 048+20:** Sidewall and haunches up and down, brickwork, bulging 75mm with random vertical and longitudinal fracture, maximum width 1mm, hollow, area 20m² (**Deformation Point 1**);
 - **Ref: Photo 36, 046+10:** Refuge down, brickwork, spalling, depth 100mm, area 2m² vertical fractures, length 1.6m to both quoins, hollow. (**Deformation Line 2**);
 - **Ref: Photo 32, 042+13 – 042+20:** Low Haunch Up and Down, brick work, longitudinal cracking, 27m, 1mm width. Various bricks crushed and spalled to downside, depth 25mm, area 3m². (**Deformation Line 3**).



Insert 14: Records of deformation relative to Cymmer Tunnel (Balfour Beatty, 2020)

- 4.154 As shown in Insert 14, the position of the deformation points coincides with a possible fault identified and where a significant surface tension crack/fissure has been observed on-site. The depth of the tunnel at this location relative to ground level is unknown at this stage.
- 4.155 A possible hidden shaft is noted (ref. 016+18, photo 23) however, this is located some 500m south of the site and therefore no further investigation is considered necessary.
- 4.156 Further survey/investigation works should be undertaken with regards to the deformation recorded in the tunnel, e.g. obtain recent tunnel inspection records (2021/2022) and consider a up to date visit if needed. The information should help understand any potential subsidence risks for the tunnel, notably in the north of the site where the tunnel is relatively shallow to the ground level.
- 4.157 Further enquiries should be made to obtain all information available to incorporate to the Ground Model.

PEAT

- 4.158 Peat deposits are recorded on the geological mapping immediately southeast of the site, expected to comprise an organic-rich clay or accumulation of wet, dark brown, partially decomposed vegetation. Site observations (Aecom, 2017) preliminarily identified further peat and as such, a peat survey was commissioned.

Previous Assessment

- 4.159 An Initial Peat Survey (desk based) was undertaken by Aecom (December 2017) followed by a Summary of Findings in Relation to the Peat Survey (May 2018) which includes the findings of a ground investigation undertaken by Terra Firma (April 2018). The findings of the assessments are summarised below;
- BGS and OS mapping indicate evidence for peat to be present beyond the geological mapped deposits e.g., ponds, boggy ground etc.
 - A site walkover identified six areas where potential peat or organic rich soils may be present (Areas A to D).
 - Preliminary ground investigation was recommended and subsequently undertaken in 2018 comprising hand excavated trial pits and TRL probing.
 - Deep peaty soils (>0.5m depth) was encountered in four trial pits in the south eastern site extent.

Deep Peat Definition

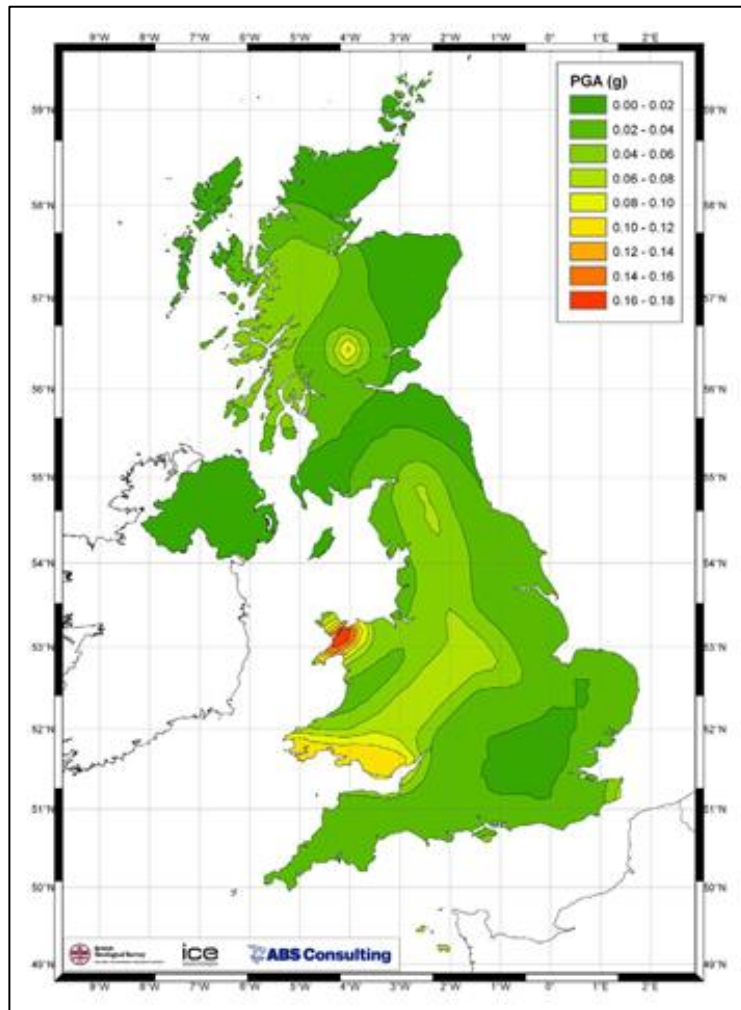
- 4.160 Previous assessments have used a depth of 0.5m to define the boundary of peat and deep peat. We understand that this was partly derived by a Scoping Opinion Addendum (ref. P2017/0825 dated 12th December 2017) provided by Neath Port Talbot County Borough Council that stated that areas of deep peat (defined as over 50cm in Wales) will be expected to be retained.
- 4.161 Deep peat is defined by the UK Forestry Standards (UKFS) as soil having a predominantly organic (peat) layer of a depth greater than 0.5m. The Forestry Commission Wales (FCW, 2022) also defines areas of deep peat as greater than 0.5m. For the purpose of the assessment, deep peat is considered as a peat layer greater than 0.5m in thickness.
- 4.162 The Welsh Government Data Maps Wales website that provides the WOM21 Deep Peat and Modified Deep Peat maps state that 'Deep peat is defined in the UK Forestry Standard (UKFS) as soil having a predominantly organic (peat) layer, of depth greater than 50 cm. Deep peat is especially important as a resource in Wales, as a carbon store, as well as an important substrate to support specialist habitats.'

Detailed Ground investigation

- 4.163 As part of the current assessment, ESP have been instructed to undertake detailed ground investigation works to delineate the extent of deep peat at the site. The findings of the ground investigation are to be presented separately once complete.

SEISMIC HAZARD

- 4.164 A study of the seismic hazard zones across the UK was undertaken by the British Geological Society (BGS, 2007), which produced hazard zoning maps for the UK. Reference to the guidance indicates that the site lies in or near an area with a peak ground acceleration (PGA) of between 0.10 – 0.12g as shown on Insert 15 below.



Insert 15: Peak Ground Acceleration (PGA) hazard map (25,000 year return period) (BGS, 2007)

- 4.165 Numerous faults are known to cross the site and further unmapped faults may be present. Landslides are also present on site and the status of these landslides is unknown at this stage (dormant/active). The site is located in an area of relatively (to the UK) higher risk of seismic activity, this should be considered further in accordance with Eurocode 8 (1998). Seismic activity may result in fault reactivation or cause landslides.

ADDITIONAL GEOTECHNICAL CONSIDERATIONS

Shrinkable and Swelling Soils

- 4.166 If encountered, the fine grained weathered upper portions of Coal Measures bedrock can be susceptible to volume change with changes in moisture content (shrinkage and swelling). Therefore, we consider that the potential for shrinkable/swelling soils at the site should be advanced from that reported in the environmental data report (Very Low) to **Moderate**.

Unexploded Ordnance

- 4.167 The environmental data report does not consider the potential risk from unexploded ordnance at the site. A Preliminary UXO Risk assessment has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix G (1st Line Defence, 2022).
- 4.168 The assessment concludes that ‘the risk from UXO is not considered to be elevated higher than the ‘background risk’ of UXO within this area of the UK. Whilst it would be possible to conduct a Detailed UXO Risk Assessment, it is not anticipated that any further findings would significantly alter the risk of encountering unexploded ordnance within the site. It is therefore recommended to that no further action is taken.’

RADON HAZARD

- 4.169 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.
- 4.170 The environmental data report (Appendix B) indicates that the southern portion of 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. We consider this coincides with the mapped Llynfi Member.
- 4.171 Reference to the published BRE guidance in BRE 211 (Scivyer, 2007) indicates that the site lies in a 1km square where the maximum requirements are for basic radon protection measures in new buildings (domestic or non-domestic).
- 4.172 Given the currently available information, the risk from radon is considered **Moderate** and new buildings should have basic Radon protection. Further assessment may allow a zoned approach to the site.

5.0 GEO-ENVIRONMENTAL GROUND MODEL

- 5.1 The following sections provide a summary of the geo-environmental setting based on information obtained from sources as previously indicated alongside previous assessments.

GEO-ENVIRONMENTAL SETTING

- 5.2 A Phase I Geo-Environmental Desk Study has previously been undertaken for the site (BSP, 2017). Salient information from the assessment is summarised below;

- The site historically comprised open moorland/rough pasture and open fields.
- Infrastructure relating to historic quarry and coal mining, including mine shafts are noted.
- On site potential contamination sources identified include general Made Ground, PAH's within ashy Made Ground.
- Hazardous ground gas sources include abandoned shallow coal mine workings, potentially infilled quarry features and localised peat deposits.
- Phase II exploratory ground investigation was recommended to include near surface sampling and soil analysis and the installation of ground gas and groundwater monitoring points.

- 5.3 In order to satisfy planning actions, initial ground investigation is currently underway and being carried out concurrently with this report.

POTENTIAL CONTAMINATION SOURCES

- 5.4 Based on the information available and our own review, we consider that although the site has remained largely undeveloped, the following sources of soil and gas contamination may be present on site in localised areas:

- Made Ground –inc. relating to mast/reservoir construction– general diffuse contamination near to these features (both technically outside red line planning boundary and off-site);
- Made Ground – potentially historic infilled ground from mining/quarrying/unspecified pits, or spoil heaps, given age infill likely to comprise mining spoil/discarded quarry stone, walkover suggest no obvious sign of contamination;
- Possible contamination within Topsoil - general diffuse contamination;
- Fly tipped material providing isolated point sources;
- Peat – on site gas source;
- Infilled mining features with Made Ground – on site gas source;
- Abandoned coal mine workings – on and off-site gas source;
- Abandoned tunnel – on and off-site gas source and potential receptor; and
- Made Ground and Coal Measures bedrock – potentially contain pyrite, diffuse source.

- 5.5 Overall, we consider the sources outlined above are likely to be localised and are unlikely to pose significant risk to the proposed development.

- 5.6 It is understood that ground investigation is required to satisfy Condition 29 of the outline planning obtained. It is proposed to undertake extensive exploratory site assessment comprising sampling of the shallow soils across the site. Dependent on the initial findings, further targeted ground investigation, sampling and analyses may be required, and this should be undertaken in general accordance with BS5930:2020 and BS10175:2017. If required, it may be prudent to undertake the targeted investigation and assessment once the design proposals are finalised and after a review of the initial phases are complete.

6.0 GEOTECHNICAL RISK REGISTER

GEOTECHNICAL CATEGORY

- 6.1 We consider that the proposed development would be classified as Geotechnical Category 2 (BS5930:2020).

RISK REGISTER

- 6.2 The Geotechnical Risk Register for the proposed scheme, based on the findings of this study is presented in Table 13 overleaf. The scales of likelihood and consequences of risk are shown in Table 12a and 12b below, with the degree of risk summarised in Table 12c.

Table 13a: Scale of Likelihood

Likelihood	Scale
Improbable	1
Remote	2
Occasional	3
Probable	4
Frequent	5

Table 12b: Scale of Consequences

Consequence	Scale
Insignificant	1
Marginal	2
Serious	3
Critical	4
Catastrophic	5

Table 12c: Degree of Risk

Degree of Risk	Risk Level	Recommended Response
1 to 5	Low risk	Broadly acceptable, if all reasonably practicable control measures are in place.
6 to 8	Medium risk	Tolerable only if further mitigation is not reasonably practical and there is a need to continue activity with identified controls.
9 to 15	High risk	Apply further mitigation measures and/or alter method of work to achieve further reduction in risk.
16 to 25	Very high risk	Unacceptable. Re-examine/re-plan activities to achieve lower level of risk.

Table 13: Geotechnical Risk Register

Hazard	Development Area	Consequence	Initial Risk Index			Mitigation Measures	Mitigated Index			Risk
			L	I	R		L	I	R	
Geotechnical Risks										
Made Ground (unknown composition)	All parts of site	- Risks to health from contamination/ soil instability. - Excess arisings disposal costs. - Potentially compressible soils.	3	3	9	Shallow Made Ground anticipated in localised areas of development and former <u>mine</u> shafts. Ground investigation to delineate and characterise Made Ground on site.	2	3	6	
Shallow groundwater – high permeability of Rhondda Formation (sandstone)	All parts of site	- Flooding of excavations. - Artesian pressures. - Running sand in weathered layers.	2	3	6	No groundwater flooding potential identified in the desk study. Groundwater anticipated within underlying Rhondda Beds bedrock – depth to be determined by ground investigation. Historic coal mining may impact groundwater regime, possible rebound. Groundwater installations to characterise groundwater regime. Employ appropriate construction drainage methods.	2	3	6	
Soil shrinkage/swelling	All parts of site	Settlement of shallow spread foundations.	2	4	8	Ground investigation to provide suitable foundation strata and foundations to be placed in below shrinkable soils or in accordance with guidance to mitigate the risks from shrinkable soils (NHBC Chapter 4.2)	1	4	4	
Compressible ground - General	All parts of site	Soft compressible soils can lead to unacceptable settlements/bearing capacity failures.	3	3	9	Ground investigation to delineate and characterise shallow soils and assess potential for soft compressible soils. Structure to be designed to bypass soft soils.	2	3	6	
Compressible ground - Peat	<u>South east</u>	- Soft compressible soils can lead to unacceptable settlements/bearing capacity failures. - Peat potentially <u>in excess of</u> 4m depth identified in initial ground investigation.	5	4	20	Areas of thick peat to be avoided and protected. Peat less than 0.5m deep can either be removed or bypassed, subject to design and regulator approval.	2	3	6	
Very dense strata/ shallow bedrock	To be confirmed following <u>preliminary SI</u>	- Difficulty in excavation within hard strata. Large areas of cut anticipated. - Difficulty with pile driving. - Programme delays and increased costs.	4	3	12	Ground investigation to delineate and characterise shallow soils and potential for hard strata. Foundations to be designed to limit dig depth in shallow rock. Costs to be programmed in to reduce unexpected costs, delays. Consider using excavated rock as resource to offset costs.	4	2	8	
Sulphate/pyrite attack	To be confirmed following <u>preliminary SI</u>	High levels of sulphate or pyrite can lead to damage to buried concrete.	3	4	12	Determine sulphate and potential pyrite content of soils and shallow groundwater. Design accordingly.	1	4	4	
Surface water flooding	<u>South east</u>	- Surface water flooding of excavations. - Damage to site plant/equipment. - Increased risk of water borne diseases. - Programme delays and increased costs.	2	3	6	Surface water flooding assessment suggests low to moderate risk. Risk assessment may be required, it may be prudent to confirm this with the regulatory authority.	1	3	3	
Unforeseen ground conditions	All parts of site	Increased costs and delays to construction programme.	3	4	12	Sufficiently detailed desk study and ground investigation to adequately delineate and characterise soils and groundwater beneath site.	2	4	8	
Instability of existing structures	South central area	- Telecommunications mast - Increased costs and delays to construction programme.	2	5	10	Mast and reservoir owners, operators to be contacted at an early stage of development to confirm site proposals and allow any required measures in design stage. No other significant structures identified, some <u>dry stone</u> walls and abandoned settlements on site which will need consideration to protections, removal.	1	5	5	
Unexploded ordnance	All parts of site	- Death or injury to site workers/ members of public. - Delays to programme through UXO clearance.	3	5	15	Preliminary UXO risk assessment obtained for scheme. Risk considered to be low.	1	5	5	
Ecology	All parts of site	- Ecological restrictions related to common lizards, breeding birds, invasive non-native <u>species</u> and general land of ecological value. - Delays to programme through vegetation/ecology clearance	3	3	9	All works are to be overseen by an Ecological Clerk of Works (ECoW) and design and programme to account for such provisions at an early stage to limit any disruption.	2	3	6	

Hazard	Development Area	Consequence	Initial Risk Index			Mitigation Measures	Mitigated Index			Risk
			L	I	R		L	I	R	
		works.								
Archaeology	All parts of site	- A number of archaeological sites exist within the development boundary including two assets of high archaeological importance. - Unforeseen archaeological findings causing delays to construction programme or requirement for development redesign.	3	3	9	Mitigation measures will be required during ground investigation and construction works including archaeological watching brief and monitoring. High importance features are to remain undisturbed.	2	3	6	
Earthquakes	All parts of site	- The site is in or near a 0.10-0.12 Peak Ground Acceleration Area (PGA) Eurocode 8 Fig 16. - Potential for an earthquake to impact on possible reactivated faults.	2	3	6	Design needs to accommodate for potential seismic events, notably in areas of possible reactivated faults.	1	3	3	
Earthworks	All parts of site	Proposed levels for the development are not known. There are several steep slopes on site that may need manipulation. These slopes may also be associated with grabens, fissures. Rock is anticipated to be relatively shallow, and costs could be relatively high to reduce levels.	4	4	16	Undertake a ground investigation to understand depths of rock. Plan development accordingly to reduce level manipulation, especially in areas of possible instability and landslides.	3	4	12	
Sustainable Drainage (SuDS)	All parts of site	Feasibility of shallow soakaways not known.	5	4	20	Investigation should determine soakaway rates across the site to ensure early design allows for drainage accordingly.	3	4	12	
Mining Risks										
Mining subsidence – Shallow mine workings	Most site areas	- Collapse of ground above mining voids - subsidence - Additional costs associated with remediation works, possible change of design - Danger to persons, assets in areas of subsidence	5	5	25	Shallow mine workings within the No.2 Rhondda anticipated in the central and eastern extents. Unrecorded shallow mine workings within the No1. Rhondda and No1. Rhondda Rider are anticipated in the western and central portion. Moderate to high risk identified across the site. Preliminary ground investigation comprising rotary drilling required for initial coal mining risk. Further detailed ground investigation and remedial works (e.g. grouting) likely required. In addition to drilling and grouting, different design mitigation could be considered, including rafts, flexible structures and management strategy.	3	5	15	
Mining subsidence – Deep mine workings	All areas, but significantly western portion.	- Collapse of ground above mining voids. - Long term subsidence associated with longwall mining - Additional costs associated with remediation works	5	4	20	Longwall mining within the No.2 Rhondda recorded in the western portion at 180m depth. Further detailed coal mining assessment required following ground investigation of shallow historic mining. Ground investigation required and possibly some remedial works (e.g. grouting) if zero risk was required. Different design mitigation could be considered, rafts, flexible structures and management strategy.	3	5	15	
Collapse of known Mine entries	All parts of site	3no. mine shafts and 1no. adit identified on site. Further mine entries anticipated from site walkover. - Compressible soils anticipated in areas of former mine shafts. - Stand-off to be incorporated into detailed development design.	4	5	20	Obtain coal authority records of shaft remediation. Confirm location of mine shaft with ground investigation e.g. trenching or geophysical survey. Stand-off distance to be agreed with Coal Authority (possibly 30m) and incorporated into detailed development design. Consider treatment to reduce stand off in design.	2	5	10	
Collapse of unrecorded mine entry	All parts of site	Mine working may be present on site, notably in areas of shallow coal outcrop – adits, bell pits. Mine shafts anywhere on site could also be present.	4	5	20	Ground investigation to understand ground model, risk to be discussed with designers and future groundworkers. Consider an allowance of time and money to mitigate risks from unrecorded mine entries in programme.	3	5	15	
Air Shaft		1no. airshaft identified on historical mapping and as part of archaeological assessment. - Nature of airshaft is unknown e.g. related to coal mining or Cymmer tunnel	3	3	9	Obtain records of air shaft from relevant body. Confirm presence/absence of airshaft on site.	2	3	6	

Hazard	Development Area	Consequence	Initial Risk Index			Mitigation Measures	Mitigated Index			Risk
			L	I	R		L	I	R	
Cymmer Tunnel	Central area	- Collapse of ground above former rail tunnel. - Collapse of possible unrecorded, unknown air/construction shafts.	2	5	10	Obtain records of former rail tunnel from Highways England, including entrance/exit points, depth to crown and details of previous surveys. Confirm any stand off zone required by Highways England and confirm measures to ensure development out of possible subsidence zones, notably in the north of the site.	1	5	5	
Landslide Hazards and Ground Stability										
General Slope instability	All parts of site	- Site identified as steeply sloping. - Historic and recent mapping indicate the presence of shallow and <u>deep seated</u> landslides.	4	5	20	Desk based assessment and geomorphological mapping identified key areas including the central landslide complex, southeast graben zone and northwest landslide. Site has been zones from medium to very <u>high risk</u> dependent on feature – See Figure 11. Ground investigation required to delineate extent and nature of landslides.	3	5	15	
Central Landslide – Landslide 1	Centre of site	- BGS mapped landslide looks to be rotational and development proposals may impact toe of landslide which may destabilise landslide. - Road to be placed over landslide may deform. - More recent movement in rear scarp of landslide.	3	5	15	Avoid development on the toe, removal of the toe of the landslide. Avoid development on the head of the landslide. Ground investigation and specific risk assessment required to understand site specific risks, <u>design</u> and possible remedial/mitigation options to be done in early phases of design. Ongoing risk to be conveyed to client to allow for possible works later in the <u>schemes</u> lifetime.	3	4	12	
Central Landslide – Landslide 2	Centre of site	- Large scale rock deformation possibly moving along a planer surface at depth, possibly associated with a seatearth or mudstone. - Movements not easily estimated and some uncertainty when occurred. - Toe of landslide not easily definable, may cover a larger area of the site that anticipated, extending to the northern boundary of the site.	3	5	15	Ground investigation required to understand possible landslide extents and depth. Avoidance of landslide recommended until risk fully understood with further investigation and assessment. Ongoing risk to be conveyed to client to allow for possible works later in the scheme lifetime.	3	5	15	
Northwest Landslide	Centre of site	Landslide looks to be degraded and shallow with no signs of recent movement. Development proposals will see some alteration to landslide which could induce movement.	3	5	15	Avoid development on the toe, removal of the toe of the landslide. Ground investigation and specific risk assessment required to understand site specific risks, <u>design</u> and possible remedial/mitigation options to be done in early phases of design. Ongoing risk to be conveyed to client to allow for possible works later in the scheme lifetime.	3	4	12	
Rock fall	<u>North western</u> area	What is considered to be relatively infrequent rock fall is occurring on slopes in the northwest of the site. Blocks have travelled a considerable distance and will consideration for the site proposed use.	3	5	15	Ground investigation to undertake kinematic analysis and rock fall analysis to allow suitable mitigation measured to be designed.	1	5	5	
Fault Reactivation	Central, <u>southern</u> and eastern areas	Several grabens or fissures have been noted on site, notably in the south and eastern portions. Coal mining may have exacerbated movement through fault reactivation. They present issues for construction and movement across the site.	4	4	16	Ground investigation to try and locate fault blocks, <u>differences</u> and map fissures. Investigation to also provide assessment on mining influences and possible impacts on surface. Proposed development to avoid fault zones. Mitigation required to infill/manage some smaller fissures.	2	4	8	
Potential Graben Area	Eastern area	A series of possible grabens and fissures have been found in the south, and east of the site. Some have steep sides slopes with drops of 5m or more. Movement may have ceased or be continuing at a slow rate.	3	4	12	Ground investigation to be carried out to understand if any movement occurring and <u>confirm or</u> provide a sound justification for their mechanism and potential locations on site. Area should be avoided, or development proposals should account for potential ground movements. Ground level proposals should be carefully designed.	2	8	8	
Sag Ponds	<u>South eastern</u> area	Two ponds <u>are located in</u> a suspected graben, which have deep peat associated with them.	3	4	12	Development will not be permissible in this area due to the deep peat. Its is recommended the ponds are maintained for the scheme and risks for the hazards they present to site users should be managed by appropriate risk assessments.	1	4	4	

Hazard	Development Area	Consequence	Initial Risk Index			Mitigation Measures	Mitigated Index			Risk
			L	I	R		L	I	R	
Ground Investigation Risks										
Working on sloping ground		Toppling/sliding of investigation plant resulting in damage to plant/injury to site personnel.	3	4	12	Careful considered location of exploratory holes. Use of specialist drilling rigs or create appropriate access as required.	2	4	8	
Traffic		Death or injury of site personnel or public.	3	4	12	Install appropriate traffic management for investigation if working in the vicinity of traffic. Appropriate PPE.	2	4	8	
Encountering unexpected services		- Injury to site staff and general public. - Disruption of service provided by statutory utilities. - Potential prosecution and compensation claims. - Significant programme delays.	5	5	25	Obtain utility plans from statutory providers. CAT scan all excavations and follow all methods of HS(G)47. Operate 'Permit to Dig' protocol.	1	5	5	
Working near surface water		Death or injury of site personnel.	3	5	15	Barriers to be set up at a suitable stand off zone to prevent access to water features. Site specific risk assessment to be carried out if work near water required.	1	5	5	
Overhanging low tree branches		- Obstruction of access, - Damage to plant or injury to site personnel.	4	2	8	Relocate boreholes as required, remove branches as required.	1	2	2	
Pollution of aquifer.		Creating migration pathways for contamination in investigation.	3	3	9	Undertake desk study to assess potential for pollution. Where necessary adopt aquifer protection (e.g., telescoped casing, bentonite seals). Adopt good construction practices (e.g. refuel in designated areas, maintain spill kits etc.)	1	3	3	
Ecology		- Ecological restrictions related to common lizards, breeding birds, invasive non-native species and general land of ecological value. - Delays to programmed through vegetation/ecology clearance works.	2	3	6	All works are to be overseen by an Ecological Clerk of Works (ECoW). Working methods to be agreed in advance.	1	3	3	
Archaeology		- A number <u>of archaeological</u> sites exist within the development boundary including two assets of high archaeological importance. - Unforeseen archaeological findings causing delays to construction programme or requirement for development redesign.	2	3	6	Mitigation measures will be required during ground investigation and construction works including archaeological watching breid and monitoring. High importance features are to remain undisturbed.	1	3	3	
Geo-environmental Risks										
Contaminated Soils		- Death or injury of site personnel or public. - Contaminated sites environs.	2	4	8	Desk study to determine contaminants of concern, inspect shallow soils, undertake laboratory testing to determine levels of soil/water contamination. Remediate as necessary based upon risk assessment.	1	4	4	
Hazardous Ground Gas		Death or injury of site personnel or public.	3	5	15	Desk study to assess risk. Moderate risk identified to construction and maintenance workers working in confined spaces. Install gas monitoring wells to further assess risk.	2	5	10	
Notes to Table 13:										
1. Risks to be updated following ground investigation phases.										

7.0 PROPOSED INITIAL GROUND INVESTIGATION

PROPOSED FIELDWORKS

- 7.1 A proposed intrusive ground investigation is detailed in the table below, it should be noted that detailed development design has not been finalised at this stage and the following proposed ground investigation will need to be reviewed following the development of a final development masterplan. The exact number and location of investigation points is to be confirmed.
- 7.2 The investigation should be designed and supervised by an appropriately qualified engineer and carried out in accordance with BS5930:2020, BS EN1997-2:2007 (parts 1 and 2), BS 10175:2011, BS EN ISO 14688 (parts 1 and 2), BS EN ISO 14689, BS EN ISO 22475 (parts 1–3), BS EN ISO 22476 (parts 1–15), BS EN ISO 22282 (parts 1–6), BS 1377:1990 (parts 1–9), BS EN ISO 17892 (parts 1–12), BS EN ISO 18674 and CL:AIRE 2021 Good Practice for Risk Assessment for Coal Mine Gas Emissions.

Table 14: Proposed Investigation

Investigation feature/hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Bedrock geology and ground model	Rotary core boreholes spread across the site to confirm underlying stratigraphy, using coal seams as marker beds. Rotary open holes could be considered between cored holes to confirm the model in some areas.	Numerous and variable upon location. Positioned to understand the ground model across the entire site.	SPT-N testing at Regular intervals within superficial deposits. Disturbed samples of soil and rock.	Variable, some gas and groundwater wells.	Determine the general ground conditions across the site. Some areas may require the generation and clearance of access routes. Some already being undertaken as initial investigation, requirement to be reviewed. Consider installation inclinometers in the northern portion of the site where access allows to confirm general stability in northern steep slopes.

Investigation feature/ hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Investigation feature/ hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Geo-environmental Assessment including ground gas assessment	Mechanical trial pitting. Understand variability of shallow soils, presence of Made Ground.	Dependent upon bedrock depth and ground conditions. Up to 3 to 4m depth.	Small disturbed and bulk samples.	None.	Some already being undertaken as initial investigation, requirement to be reviewed upon completion, or as part of detailed ground investigation phase to achieve suitable sampling density.
	Rotary cored boreholes spread across the site and targeted for gas sources (workings, shafts, faults, peat)., pathways and receptors	Dependent upon Ground Model. Sufficient number to characterise site and gas sources to enable thorough gas risk assessment.	None, however, samples and testing could be undertaken to aid understanding for other investigations on site.	Deep and shallow ground gas wells, 50mm diameter. One well per response zone.	Positions could be used in conjunction with other boreholes required across the site as detailed in this table if Ground Model allows.
	Rotary core boreholes spread across the landslide to confirm underlying stratigraphy, using coal seams as marker beds where present.	Dependent upon Landslide depth, prove base of landslide, aim to drill through into Llynfi Member.	SPT-N testing at Regular intervals. Disturbed samples of soil and rock.	Groundwater vibrating wire piezometers with data loggers. Inclometers to below base of landslide.	
	Trial pits or trial trenches at toe of landslide.	Sufficient number to accurately map toe of landslide.	Small disturbed and bulk samples. Hand vanes in fine-grained material. Soil sampling for shear box testing.	None.	Determine geometry, stratigraphy and geotechnical properties of the landslide materials and the materials at the base of the landslide.
Central Landslide Complex - Landslide 1					

Investigation feature/hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Central Landslide Complex - Landslide 2	Rotary core boreholes spread across the landslide to confirm underlying stratigraphy, using coal seams as marker beds where present.	Dependent upon Landslide depth, prove base of landslide, aim to drill through into Llynfi Member.	SPT-N testing at Regular intervals.	Groundwater vibrating wire piezometers with data loggers. Inclimeters below landslide depth.	Determine the groundwater conditions/profile through the landslide. Aid assessment in understanding if landslide is dormant/active.
North western Landslide	Rotary core boreholes spread across the landslide to confirm underlying stratigraphy, using coal seams as marker beds – access may require specialist slope climbing rigs to be used.	Dependent upon Landslide depth, prove base of landslide, aim to drill into hard strata.	SPT-N testing at Regular intervals. Small disturbed and bulk samples in superficial soils.	Groundwater vibrating wire piezometers with data loggers. Inclimeters below landslide depth.	
	Trial pits or trial trenches in toe of landslide.	Sufficient number to accurately assess landslide.	Small disturbed and bulk samples. Hand vanes if Fine grained material. Samples for shear box testing.	None.	
Investigation feature/hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Deep peat area	Drill boreholes using windowless sample rig and install ground gas monitoring wells	Assume 4no. to depths of the base of the peat, (0.5m to greater than 4m (access dependent)).	SPT-N testing at Regular intervals. Small disturbed and bulk samples.	50 mm dia. Groundwater and gas Standpipe.	Access dependent.

Investigation feature/ hazard	Aims and Methods	Proposed Number and Depths	Proposed Sampling and Testing	Proposed Monitoring Installation	Comments
Graben Area	Rotary core boreholes spread across the graben area to confirm underlying stratigraphy, using coal seams as marker beds where present.	Variable, dependent upon dip (structurally altered?) and borehole locations. Aim to prove base of No.2 Rhondda and into Llynfi Member.	SPT-N testing at Regular intervals. Small disturbed and bulk samples in superficial soils.	Some instrumented with groundwater piezometers with data loggers.	Determine ground model, and fracture state of rock in graben area.
Mine entries	Trial pits or trial trenches near to marked, or suspected mine shafts.	Sufficient number to accurately identify each mine shaft.	None specifically proposed unless Made Ground identified.	None.	Access dependent.
	Geophysical Methods (e.g. conductivity and magnetometry).	50 x 50m grid at each recorded mine shaft location.	None.	None.	Grid area's likely to require minimal vegetation clearance.
Rock Fall	Undertake discontinuity survey and rock mass assessment with detailed exposure mapping.	None.	None.	None.	None.

Notes:

1. Table to be updated following completion of preliminary Ground investigation and development of finalised development masterplan.
2. Building specific investigation may need to be carried out in due course once site layout known and excavations, foundations known.
3. Gas monitoring wells to be installed in rotary cored and windowless sampler boreholes across the site and gas monitoring undertaken to understand ground gas regime.
4. Restrictions relating to vegetation clearance or ecology have not been considered and it is assumed that access will not be restricted. Where not feasible, the proposed investigation point would be moved. Individual positions can be amended to suit, assuming aim are still achieved.
5. Further targeted geo-environmental investigation may be required once land uses known and following review of initial phase of investigation.

7.3 Access to the borehole and trial pit positions will have to be agreed within the ecological restrictions placed on site.

PROPOSED LABORATORY TESTING

- 7.4 Geotechnical laboratory testing will be required to be undertaken to determine the geotechnical classification (moisture content, grading, plasticity etc.) of the encountered soils, and where possible, the drained and undrained shear strength parameters (either using a triaxial cell for fine-grained soils) or a shear box (coarse-grained soils).
- 7.5 The sulphate content and pH value of the soils shall also be determined.
- 7.6 Selected soils should be analysed for a range of contaminants typically found on brownfield sites within the UK, including metals and semi-metals, polyaromatic hydrocarbons, cyanide and asbestos. The soils will also be analysed for petroleum hydrocarbons (which could be indicative of vehicle leaks and spills). No groundwater or leachate testing is proposed at this stage.
- 7.7 The sampling and testing density will vary depending upon the investigation requirements, but should be in general accordance with guidance and standards.

OTHER INVESTIGATIONS

Geophysics

- 7.8 Consideration could be given to the use of geophysics to either help zone or identify specific features of interest, such as landslide bases, landslide extents, mining features and potential for unidentified grabens. The use of geophysics may require some physical investigation to confirm/collaborate the assessment, and this should be appreciated if this approach is adopted.

Detailed InSAR Assessment

- 7.9 The InSAR information we have obtained in this scoping and morphological assessment suggests some movement of the surface which is tentatively attributed to mining subsidence.
- 7.10 It may be beneficial to understand if further, more detailed InSAR data could be obtained to refine the areas of movement to help develop the ground model. Such a survey should cover the entire site and other areas of nearby interests, such as Cymmer to the north, and the land to the south of the red line boundary.

Repeat Topographical Survey

- 7.11 Grabens, landslides, fissures and possible ground subsidence have been noted on site. Current InSAR data suggest some areas of the site to be moving, whilst other areas are relatively static. Repeat LiDAR or other surveys (e.g. traditional topographical) may aid determination of ground movements and provide information on the presence/absence of graben, landslide and fissure movements. This could possibly provide another line of evidence for ground movement and be compared with the InSAR data.

Tunnel Survey

- 7.12 Preliminary information has been provided from National Highways regarding the tunnel as outlined previously. Further enquiries should be made to obtain all information available to incorporate to the Ground Model and a tunnel survey should be undertaken in line with CIRIA C671 (2010).

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