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Cilmaengwyn Landslide, Tawe Valley
Preliminary Landslide Assessment

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Cilmaengwyn Landslide
Preliminary Landslide Assessment

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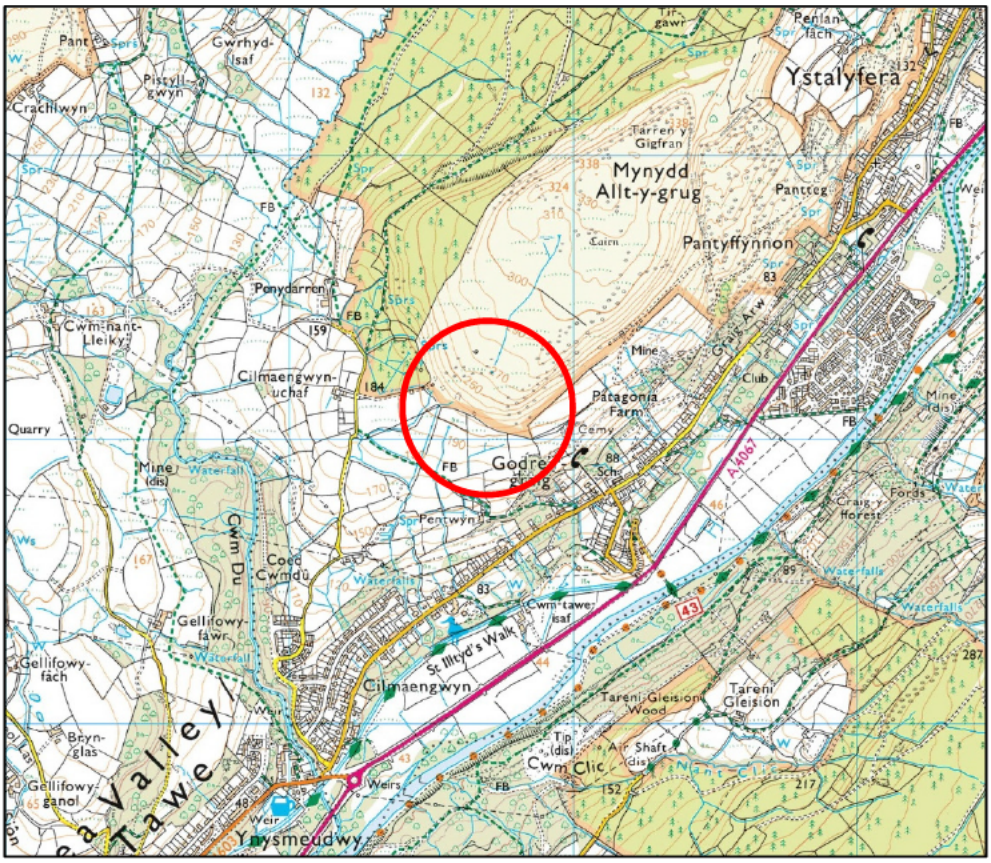
1 INTRODUCTION

1.1 Background

Neath Port Talbot County Borough Council (hereafter known as the Client) have instructed Earth Science Partnership Ltd (ESP) to undertake a Preliminary Landslide Assessment on a historically defined landslide (TW14), located to the north of Cilmaengwyn, in the Tawe Valley. The landslide was historically identified in the South Wales Landslip Survey by Conway et al in 1980.

This assessment concentrated upon TW14 but also examines the local area to provide a regional context, and thus a wider area (study Area) has also been considered. The general location of TW14 and the study area for this assessment is shown below, Insert 1.



Insert 1: General Study Area 1:25,000 (Ordnance Survey License No.: AL100015788).

The extent of the TW14 landslide is defined on the 1:10,560 Geological Map (sheet SN 70 NW), although it should be noted that the boundary in the Landslip Survey and Geological Map vary slightly.

1.2 Objective and Scope of Works

As discussed in Section 1.1, the aim of this report is to provide an assessment of the TW14 landslide, however, given the regional context of the landslide, it is considered pertinent to include information on the surrounding area to determine if any landslides are located in a similar geographical, geomorphological and geological setting. Therefore,

the starting point for this assessment is the TW14 landslide and evidence collected in the wider desk study will be used in this assessment.

The historical boundary of the TW14 landslide and the wider area, considered for this assessment as similar in topographical, geological and geomorphological setting is shown on Figure 1. It should also be noted that information from previously reported landslides outside of the study area has also been used to provide context to the TW14 landslide, where this information is provided in the text, the relative location is discussed as required.

The scope of works for the investigation was mutually developed with the Client and ESP within an agreed budget, and comprised:

- a geological and historical desk study;
- obtain aerial photograph and subsequent interpretation, including stereographical analysis;
- brief site visit for orientation and initial geomorphological assessment;
- obtain low resolution LiDAR information;
- generate a preliminary geomorphological map;
- if applicable, produce a preliminary site-specific landslide inventory; and
- provide a preliminary (qualitative) assessment of the hazards/risks and define any next steps.

The assessment is being carried out using a general principals approach of landslide assessment and management. Some elements of the work, such as the data presentation, hazard identification and qualitative risk assessment are taken from the guidelines set out within a journal from the Australian Geomechanics Society (AGS, 2007) and subsequent papers to standardise its use worldwide (Fell et al 2008). However, this assessment is not in strict accordance with the above-mentioned guidance.

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 email proposal of 5th December 2017.

The assessment was undertaken in April to July 2018.

1.3 Report Format

This report includes a geological and historical desk study (Section 2), an aerial photograph interpretation including the findings of a site reconnaissance visit to undertake a preliminary geomorphological assessment of the site (Section 3). The information gained is used to undertake a Hazard Identification Assessment following general principals of the AGS (2007) guidance (Section 4) and a qualitative assessment with recommendations is provided in Sections 5 and 6 respectively.

This report is issued in a digital format only.

1.4 Limitations of Report

This report represents the findings of the brief as detailed in Section 1.1. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. It should be appreciated that no intrusive investigation has been undertaken to date. Should an alternative current land use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals or land uses.

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

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

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Specialist advice has also been provided by external consultants for the ratification that this assessment has been done accurately and to the same standard as an experienced landslide professional. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.5 Definitions for Landslide Hazard and Risk

1.5.1 Introduction

Guidelines for the assessment of landslide hazard and risk were clarified for international use by Fell et al (2008) who reported on behalf of Joint Technical Committee on Landslides and Engineered Slopes. The report by Fell (2008) is primarily based on an extract from the Australian Geomechanics Society (AGS) 2007c, Practice Note Guidelines for Landslide Risk Management, and Fell offers minor modification for international implementation.

This assessment has not been carried out in strict accordance with the Guidelines provided by Fell, however, some terminology and methods from the guidance is adopted in this assessment for a standardised approach.

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.

1.5.2 Definitions

This assessment has adopted definitions provided in the AGS (2007) guidelines for use in landslide management:

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.

Risk — A measure of the probability and severity of an adverse effect to health, property or the environment.

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

- Qualitative risk estimations are "those were 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"; and
- Quantitative 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".

1.5.3 Landslide Classification

Landslides are classified in terms of material type (rock, debris, earth) and movement type (fall, topple, slide, flow). In order to classify the slope movements in line with international use, the definitions used are broadly based upon Hungr (April 2014) and is presented in Table 1.

Table 1: Classification of Landslide Types, Hungr et al., 2014.

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

The AGS (2007) guidelines also provide a summary of Varnes (1978) classifications for rock, soil, debris and earth, and these are presented below:

- Rock – is 'a hard or firm mass that was intact and in its natural place before the initiation of movement'
- Soil – is 'an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil for part of the soil'
- Earth – 'described material in which 80% or more of the particles are smaller than 2mm, the upper limit of sand sized particles'
- Debris – 'contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2mm and the remainder are less than 2mm'.

2 DESK STUDY

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps (Appendix A) and aerial photographs (Appendix B). Further desk study reports/data/records are included as subsequent appendices as referenced in the text.

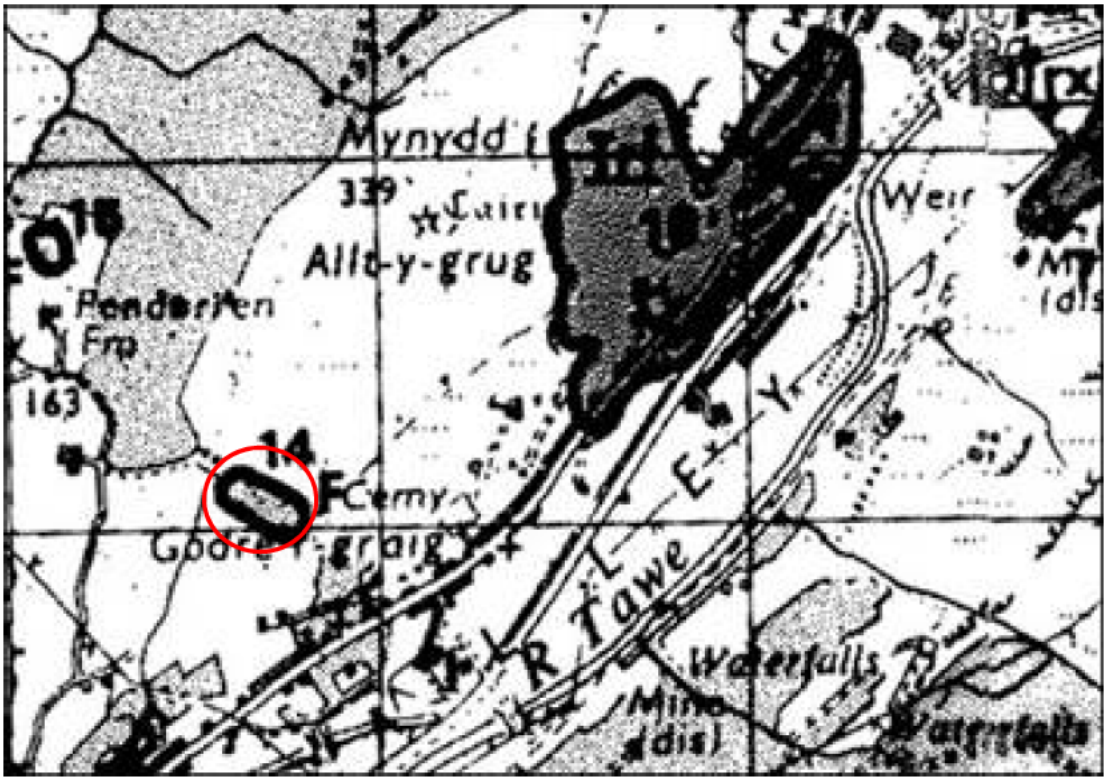
The landslide area of TW14 was visited on the 16th March 2018 during generally dry and sunny weather, and general views of the site are included as a series of photographs within the Plates section of this report.

2.1 1980 Landslip Survey

2.1.1 TW14 landslide

As discussed in Section 1.2, the boundary for the commencement of this Landslide Assessment was based upon the boundary identified for the landslide TW14 in the South Wales Landslip Survey (Conway et al, 1980). An extract of the survey showing the outline of TW14 is shown in Insert 2 below.

Insert 2: Location and initial search boundary of Landslide TW14.



The outline of the TW14 landslide has been transposed onto a more recent historical map and is provided as Figure 1.

The accompanying text for TW14, from the landslide survey, is summarised in Table 2.

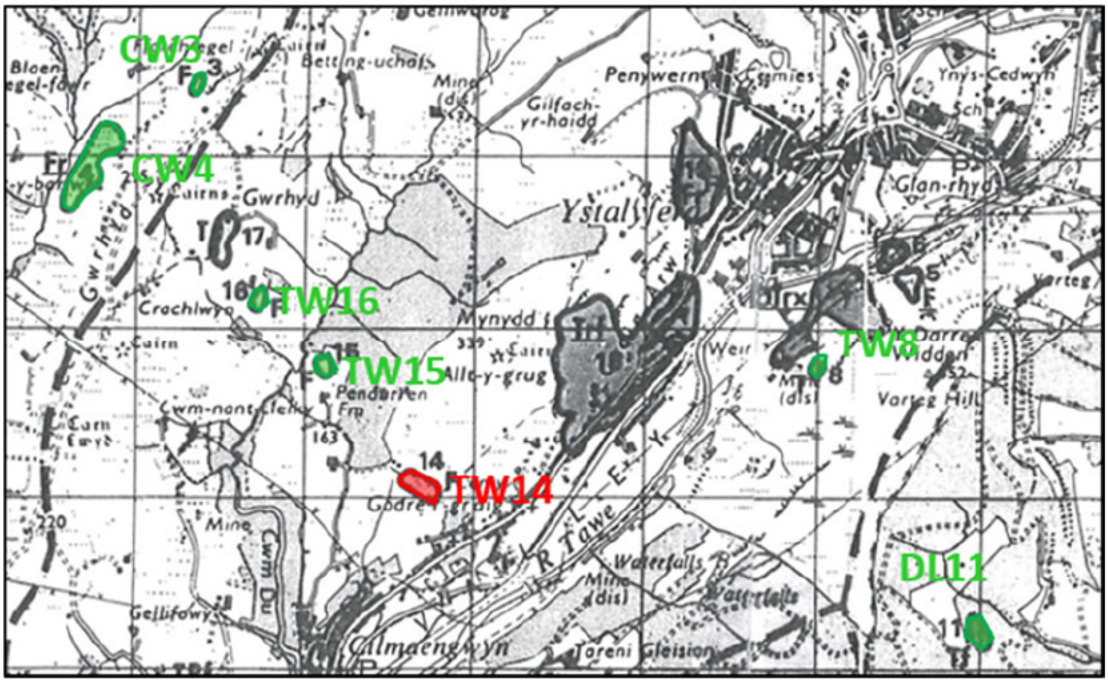
Table 2: Information in Landslip Survey for Landslide TW14

Location and **National Grid Reference**	Summary Description	Activity	**O.D. height** Top Bottom	**Downslope** length (m)	Slip **Area (Ha)**
Cilmaengwyn at the SW end of Mynydd Allt-y-Grug, 0.3km NW of Godre'r-Graig. SN 747.070	Flow. Shallow flow in Llynfi shale and superficial below the Rhondda No.2 coal seam which outcrops at the base of the Rhondda sandstone, degraded and vegetated.	Dormant	213 298[1]	60	2
Notes: 1, We have copied the date as supplied in the Landslip Survey, however, ESP believe this to be a typing error and should be 198m OD. 2,Rhondda No. 2 seam known locally as the Ynisarwed coal seam (Section 2.5.1).					

2.1.2 Other Landslide Records

The records from the Landslip Survey show no immediately adjacent landslides to TW14 on the southern side of Mynydd Allt-y-Grug, i.e. in the study area. However, there are landslides in the Tawe, and adjacent valleys, as shown on Insert 3.

Insert 3: Nearby Landslides pertinent to Assessment (not to scale)



It should be noted that there are other landslides identified in the landslip survey that are shown in the nearby area, however, these landslides are considered to be different to the Cilmaengwyn landslide for several reasons (mechanism of movement, geological setting and material), and have thus not been included in this review.

The information for the nearby identified landslides is detailed in Table 3.

Table 3: Pertinent information from the Landslip Survey

Landslide Ref	**Location and** National Grid **Reference**	Summary Description **and** Activity[3]	**O.D. height** Top **Bottom**	**Downslope** length (m) **and** Slip Area (Ha)	**ESP Comment**
TW15	Penydarren on the W flank of Mynydd Allt-y-Grug SN742.077	Shallow flow in Llynfi shale and superficial deposits below the Rhondda No.2 coal seam which outcrops at the base of the Rhondda sandstone, degraded and vegetated. Dormant	191 137	140 2Ha	Similar geological setting to TW14, (LS below No.2 Rhondda coal seam). Shallower angle of dip on geological map.
DL11	Drosgol. Western side of valley on NE flank of Mynydd Marchywell. SN 779.061	Failure movement probably transitional (translational) between slide and flow comprising superficial deposits and sandstone debris overlying Rhondda mudstones. Dormant	259 233	75 1Ha	Similar geological setting to TW14 (LS below No.2 Rhondda coal seam).
TW8	SE side of Tawe Valley above Darren Fach. SN 769.077	Shallow translational debris slide in Rhondda Beds, Llynfi Beds and superficial deposits. The top of the slip is at the level of the No. 2 Rhondda Coal Seam. Dormant	183 130	120 1Ha	Similar geological setting as TW14 on opposite side of valley.
CW4	Below Graig Ddu on the SE side of the Egel valley, 4km north of Pontadawe. SN 727.090	Shallow flows and small slumps in Rhondda shale and superficial deposits due to spring lines at junctions with interbedded Rhondda sandstone. Largely degraded and vegetated. Minor activity at strong springs. Active	236 191	150 6Ha	Similar geological setting as TW14. Note of activation where springs are present.
CW3	250m WNW of Capel-y-Gwrhyd on the	Shallow flow in superficial deposits above junction of Rhondda sandstone and Rhondda shale. Vegetated.	255 244	20 <1Ha	Similar geological setting as TW14.

Landslide Ref	Location and National Grid Reference	Summary Description and Activity[3]	O.D. height Top Bottom	Downslope length (m) and Slip Area (Ha)	ESP Comment
	north end of Cefn Gwrhyd SN 735.094	Dormant			
TW16	Pistyll gwyn, 2.5km west of Ystalyfera on the east flank of Cefn Gwrhyd. SN 737.081	Shallow flow in superficial deposits on Rhondda sandstone, degraded and vegetated. Dormant	160 145	80 1Ha	Different geological setting, however shows evidence of instability in local areas with spring lines.
	Notes: 1, The relative locations of the above landslides are shown in green on Insert 3. 2, Rhondda No. 2 seam known locally as the Ynisarwed coal seam (Section 2.5.1). 3, Conway et al (1980) defined an active slope where movement is currently occurring, morphological features are fresh, easily recognisable and no significant weathering/erosion, free water is often present. Indications for current movement include: fresh tension cracks; fresh scarps; a wet, spalling or otherwise active toe; recently tilted and/or uprooted trees; fresh cracking accompanied by heaving or subsidence of roadside verges and pavements; broken and/or displaced pipelines and drains; cracking and displacement of walls and buildings. A **dormant** state was assigned to landslips that showed no evidence of current movement as indicated by the features in the active landslide description. Their morphological features have become degraded by normal weathering processes and more or less continuous vegetation cover has developed over the slip mass.				

The survey information suggests that some of the nearby landslides (TW8, TW15 and DL11) are located at a similar geological setting, in that the instability is located at or below the No. 2 Rhondda coal seam. The movement within these locations varies from shallow flows to shallow translational slides. They were all classed as dormant at the time of the field survey, dated 1979.

Information on the CW4 landslide indicates movement at a spring line between the junction of interbedded permeable Rhondda sandstone and Rhondda shale units, which resulted in shallow flows and small slumps within the shale and superficial strata. The landslide was assessed as degraded and vegetated; however, it was noted to be active around 'strong' springs.

Whilst the landslides CW3 and TW16 are not at the same stratigraphic location, they do show that instability occurs, shallow flows, at the junction of sandstone and shale, and within superficial deposits. These landslides are small (circa 1Ha) and are vegetated and dormant.

2.2 Landslide Location and General Description of Study Area

The landslide (TW14) is located in the Tawe Valley, and the study area has been defined as the southern flank of Mynydd Allt-y-Grug between Cilmaengwyn and Godre'r Graig.

The National Grid Reference of the centre of the landslide (TW14) is (SN) 274645 207040 and the nearest postcode, which is for a nearby farm, Cilmaengwyn Uchaf Farm (410m west) is SA8 4TX.

2.2.1 Wider Study Area and General Topographic Setting

The highest point near the study area is the summit of Mynydd Allt-y-Grug in the north, which has a relatively flat summit or plateau. From the plateau, the general topography of the area slopes toward the southwest, south and southeast, initially relatively steeply. The gradient shallows at a level of around 200 to 210m OD which is at a similar level to a dry-stone wall which generally defines the change in gradient. Trees are present in the southwestern flank above and below the change in gradient.

On the southern and southwestern flanks of Mynydd Allt-y-Grug, the land above the drystone wall is generally overgrown with bracken, brambles and other rough pasture, on the eastern flank, scree slopes with some vegetation is prominent.

Below the drystone wall, the land has typically been managed for an agricultural use, with fields and hedge rows.

The Tawe Valley forms a typical U-shape valley shape, which was over steepened in the last glaciation and the valley floor is relatively flat.

2.2.2 TW14 Landslide Description

The TW14 landslide is broadly located within agricultural fields (Figure 2). The northern boundary of what appears to be the disturbed ground is broadly delineated by a dry-stone wall (Plates 2, 3, 7, 8 and 9) separating the agricultural fields to common land of Mynydd Allt-y-Grug. The western (Plate 3), southern (Plates 10 and 13) and eastern (Plates 12 and 14) boundaries appear to be within the agricultural fields.

The area identified to be the TW14 landslide is generally covered with rough grass, reeds and occasional pockets of gorse (Plates 1, 13, 14 and 15). Semi-mature deciduous trees are located in one area near the northern extent of the landslide (Plate 18).

A ditch runs along most of the rear edge of the TW14 landslide, which is considered to be the former base of the backscarp of the landslide, although this is now highly degraded and has likely been altered by man to divert water from the field and to provide water to fill livestock drinking troughs (Plate 18). The ditch does not extent the whole way along the northern boundary of the of the disturbed ground, as shown on Figures 2 and 4.

Although not fully apparent, the crown of the landslide is considered to be just north of the dry-stone wall, within the heavily vegetated Common Land.

The eastern portion of the landslide is crossed by a suspect BT cable which is on telegraph poles. A pole located near the rear scarp of the landslide, shown in Plate 8 is showing signs of movement with suspected backward rotation, the pole was measured to be 8° from vertical.

Within the landslide, there are areas that are flatter or steeper and these are shown on the geomorphological map produced for the site (Figure 4). The most notable feature is a large lobe in the central southern portion of the disturbed ground. However, typically, the upper most portion of the landslide is flatter and the southernmost is steeper in profile; this was noted to vary along the length of the disturbed material.

Standing water was noted around streams and in areas where streams were not apparent. Plate 10 shows standing water from a stream (S1) in the eastern portion of the disturbed ground. The standing water location is broadly at the edge of the disturbed material, i.e. the toe of the landslide.

2.2.3 LiDAR Data Review

We are not aware of a topographic survey, however, low level LiDAR data available from the Natural Resources Wales database has been plotted onto a base map for the site (Figure 3) and typically confirmed the general topography described above. However, the data has been plotted using 1m contours and shows a distinctive break in slope that forms the southern edge of the disturbed material, or toe of the TW14 landslide. The northern edge of the disturbed material, or crown of the landslide is less well defined, and is considered to be north of the dry-stone wall.

A review of the contours for the surrounding area, or the wider study area shows no obvious evidence of other lobes, or backscarps that may be generated from landslides. The contours generally confirm the relatively steeper slope to the north of the dry-stone wall (Section 2.2.1) and they are consistently wider spaced in the lower lying agricultural fields indicating relatively consistent topography.

The LiDAR plan generally confirms the presence of the streams as identified on Figure 2, as discussed previously.

2.3 History

2.3.1 Published Historical Maps

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

Throughout the historical review, items of interest (mining and springs) have been labelled/itemised to help reference individual features and their change throughout time as this ties into following Sections. Therefore, this section not only provides an indication of changes in land use through time (mining), it includes a review of any morphological changes that are identified by the historical maps. For ease of reference, Figure 2 labels the mining (M) and spring (S) locations.

Table 4: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1876 (1:1560)	The TW14 landslide area is undeveloped and within the northern portion of two agricultural fields.	The land to the north of the site, and above the drystone wall on the eastern flank of Mynydd Allt-y-Grug appears to be covered with rough pasture, probably part of the current Common Land. Land to the west, south and east is primarily shown in an agricultural layout (fields). An area of marsh is indicated approximately 100m south of the slide area. A quarry (M1) is shown about 25m north of the slide area. A spring (S5) is shown to be exiting the southern extent of the M1 quarry, the spring forms a stream which flows around the western edge of the landslide area into a presumably straight ditch on the field boundary. A spring (S1) is located approximately 20m north of the eastern part of the slide area. It flows directly south, crossing the slide area until it is cut-off by a ditch and generally flows toward the south. A stream (S2) is shown to flow from the summit of Mynydd Allt-y-Grug and 'spread' approximately 250m north of the slide area. A spring (S3) is located around 50m northwest of the landslide area that forms a meandering stream flowing toward the southwest. A spring (S4) is located approximately 70m northwest of the slide area and is shown to flow south for about 20m whereupon it meets a fence line and flows toward the southwest. A quarry (Cwar Pentwyn) is shown about 200m southeast of the slide area. Numerous coal levels are shown on the eastern flank of Mynydd Allt-y-Grug. Three other springs are also shown on the eastern flank of Mynydd Allt-y-Grug, at or near the 700ft (213m) contour. Another spring is located on the southwestern flank, at a level of around 650ft (198m). Cilmaengwyn Uchaf Farm house is shown in its present-day location/layout.

Table 4: Review of Historical Maps (Cont.)

Date	On-Site	In Vicinity of Site
1877 (1:2,500)	No significant change	The map labels M1 as an 'old Quarry' and shows an 'old coal level' (M2) directly to the south of the quarry, the form of the old coal level looks like an adit, associated spoil is evident within 10m of the landslide area.
1898/1899 (1:2,500)	No significant change	Another 'Old coal Level' (M3) is shown near the northern boundary of the landslide area. Further coal mine entries are indicated on the eastern flank of Mynydd Allt-y-Grug at a similar elevation, of approximately 650ft (198m).
1913/14 – 1948 (1:10,560)	No significant change.	A 'Coal Level' (M4) is labelled approximately 60m northwest of the landslide area. The spring for S3 is no longer shown, however, the stream is still evident in the lower fields. Similarly, the spring S4 is no longer shown.
1960 to 1993	The slide area is now shown as Rough Pasture and a fence appears to have been constructed along part of the southern boundary of the slide area.	A Mine, with two buildings is shown approximately 70m northwest of the site, which includes adit M4, and two other adits, M5 and M7. A railway line is shown exiting M5 and is positioned over a spoil mound, M6. The spoil mound boarders the northwestern margins of the landslide area. The mine and coal levels are labelled as disused. The spoil mound appears to have covered the spring locations of S3 and S4 and a new stream is shown that flows from near the source of S4, to S3. This new stream is removed from the maps dated between 1962 and 1986. A new spring (S6) is located near the southern boundary of the landslide area, it flows toward the southwest. The 'spreads' for stream S2 is now only 130m north of the site. The southwestern flank of Mynydd Allt-y-Grug was first labelled to have conifer trees on the 1986 map, the map indicate they were presumably planted between 1962 and 1986.
2014 to present	No significant change.	The 2014 map appears to show the stream S1 to flow toward the east and shows new springs (S7) to the southeast of the landslide area, which flow into the ditch to the south of the landslide area S1 flows into.

2.3.2 Summary of Historical Maps

The historical maps show that the TW14 landslide area has never been developed upon, and since the first map studied, it has only been in use as an agricultural field. The maps label the field as rough pasture and they do not show enough detail to delineate the landslide and it is not known if it had occurred before the first map studied.

Mining has taken place near to the northern boundary, along the suspected outcrop of the Ynisarwed. Spoil mounds are located near the northern extent of the landslide area and appear to have altered the location and form of streams.

The wider study area showed a similar trait, in that mining had occurred along the presumed outcrop of the Ynisarwed and that springs occur at a similar level. They showed no obvious signs of movement, however, given the lack of development and mappable features, such small-scale movements may not have been mapped.

2.4 Hydrology

There are numerous springs along the southern extents of Mynydd Allt-y-Grug, all at similar elevation. S1, S5, S3 and S4 all emerge at elevations of between 700ft (213m OD) 725ft (221m OD), this is typically below the Ynisarwed outcrop elevations, of around 725ft (221m OD). Figure 2 shows the locations for the streams for the site and attempts to delineate from 'natural' streams to those made by land owners/farmers.

Given the agricultural layout of the slide area and surrounding area on the first map dated, it is considered likely that some of the streams have been altered by farmers throughout time to establish dry land suitable for crops or supporting livestock. This would have been done by creating ditches along boundary lines and cutting of ditches to prevent land becoming wet further downslope. In any case, all streams in proximity to the study area flow toward the south and south-west, downhill ultimately toward the River Tawe.

As discussed in Section 2.3.1 above, the morphology of some streams change throughout the time period covered by the historical maps, and this is possibly attributed to mining activities, for example, the spring S3 was covered spoil and an additional stream was identified between S3 and S4.

However, it is not possible to know if the emergence of S6, at an elevation of 650ft (198m OD) is as a result of mining influences or, as a results of ground movements as the spring is some 15m further downslope than the majority of natural springs noted in the area.

2.5 Geology

2.5.1 Published Geology

The published 1:10,560 scale geological map for the area of the landslide (Sheet SN 70 NW) indicates that it is directly underlain by bedrock, the Llynfi Beds, which is part of the Lower Pennant Measures of the Upper Coal Measures. The map indicates the bedrock below the slide area to be argillaceous (mudstones, siltstones and sandstones), with a sandstone unit/rock outcropping approximately 70m downslope. This general geological sequence underlies the wider study area, with the exception to Glacial Diamicton being noted on the southwestern flank of Mynydd Allt-y-Grug. The geological setting of the study area is therefore largely the same, with the exception to the dip which will be shallower on the eastern flank.

The Ynisarwed (or No. 2 Rhondda) coal seam outcrops near the northern boundary of the TW14 landslide. The Ynisarwed seam forms the boundary between the (older) Llynfi Beds which underlie the site, and the overlying (younger) Rhondda Beds which comprise sandstone.

The Published Geological map indicates the presence of an unnamed seam south of the landslide area, which forms the boundary between the argillaceous rock (shale) underlying the site and the sandstone that outcrops approximately 70m south of the site.

Reference to the adjacent Published Geological Map, Sheet SN 70 NE, suggests that the unnamed coal seam might be the Payne's seam, as it is located in the same stratigraphic horizon; the Payne's Seam is shown to be up to 3ft (0.91m) thick. In addition, another coal seam, called the Pant Rhyd y Dwr is shown in the stratigraphic column between the Payne's and the Ynisarwed (or No. 2 Rhondda) this is also shown to be up to 3ft thick (0.91m).

Superficial Deposits, Glacial Diamicton and Peat are indicated within about 100m of the TW14 landslide but located in the western region of the wider study area.

The published 1:50,000 scale geological map for the study area (Sheet 230, available on the website of the British Geological Survey, 2018) generally confirms that above stratigraphy and is shown in Insert 4. The map only shows the presence of the Ynisarwed (or No. 2 Rhondda) and other large seams in the general area of the site, the Pant Rhyd y Dwr or Payne's seams outcrops are not shown.

Insert 4: Extract from BGS Solid Geology Sheet 230, 1:50,000 (BGS licence number: C15/05 CSL)

The map shows the beds in the locality of the site to be dipping toward the south at angles of between 3° and 5°.

Reference to the up-to-date mapping available on the website of the British Geological Survey (BGS, 2018) again indicates a similar succession, however the Llynfi Beds are now named the Llynfi Member and the Rhondda Beds are labelled the Rhondda Member.

From a review of the Geological Memoir for the area and memoirs of adjacent areas, where similar rock successions are encountered, it is noted that the Llynfi Member is essentially argillaceous, and contains sandstones bands within it that are generally thin and in-persistent. The strata above the No. 2 Rhondda or roof rock is understood to be a Conglomerate.

Contradicting the several geological maps above, the information in the South Wales Landslip Survey (Conway et al, 1980) indicates that the landslide was a 'shallow flow in Llynfi shale and superficials below the Rhondda No.2 Seam which outcrops at the base of the Rhondda sandstone'. Indicating that Glacial Diamicton may be present and that the bedrock is likely to comprise shale (mudstone). As part of the site walkover, soils visible from ground level were inspected and exposures of what appeared to be Glacial Diamicton were noted in the drainage ditches excavated just to the south of the landslide area. It is therefore likely that Glacial Diamicton is present over the landslide area, however, the extent and depth of which is not known.

Reference to the website of the British Geological Survey (BGS, 2018) indicates no available records of boreholes in the vicinity of the site. The pit record for the nearby colliery is not available.

2.6 Hydrogeology

The combination of the geological setting and topography of Mynydd Allt-y-Grug will dominate the hydrogeology of the study area. Simplistically, Mynydd Allt-y-Grug is formed by sandstone (Rhondda Member) that overlies a series of mudstones, siltstones (shales of the Llynfi Member). The sandstone will be relatively more permeable (secondary porosity) than the underlying argillaceous rocks and to a certain extent, the argillaceous rocks will limit downward migration of groundwater. The bedding planes of these strata all dip gently (3-5°) toward the south. These bedding planes will therefore dip out of the southern and southeastern flanks of Mynydd Allt-y-Grug and 'daylight' in the study area.

Whilst groundwater will percolate downward, due to gravity and primarily via fracture flow; some groundwater could also flow along bedding planes and near horizontal fractures and thus there may be a component of groundwater flowing out of the southern and southeastern flanks of Mynydd Allt-y-Grug, this is likely to provide the mechanism/justification for the spring lines noted, as discussed in Section 2.4.

The relatively recent introduction of workings within the Ynisarwed (or No. 2 Rhondda) and possibly the coal seams below the site will provide a preferential pathway for groundwater to drain out of Mynydd Allt-y-Grug, or out of workings elsewhere. The presence of streams discharging from the former adits (Section 2.4) correlate to the assumption that they are providing a preferential flow to a groundwater body in the overlying sandstone.

2.7 Past Coal Mining

As discussed in Section 2.5, the site is underlain by bedrock of the Upper Coal Measures, which contains several seams of coal (and bands of ironstone). The Ynisarwed (or No. 2 Rhondda) seam is shown on geological maps to crop out approximately between 15m and 30m north of the TW14 landslide area. The published geological map suggests that the seam is 1ft 6in to 2ft (0.45 to 0.6m) thick.

The geological memoirs suggest that Ynisarwed (or No. 2 Rhondda) coal seam was worked extensively across the area and evidence of this is seen in the historical maps (Section 2.3.1)

An unnamed coal seam, or a seam possibly known as the Payne's, is suspected to outcrop some 70m downslope of the TW14 slide area, and is shown to be 2ft 6in (0.76m) thick on the geological map, the adjacent map shows it to be up to 3ft (0.91m) thick.

In addition, another seam, labelled as the Pant Rhyd Y Dwr is shown in the stratigraphic column of the adjacent map between the Ynisarwed and the Payne's seam. Although this seam is not shown on the geological map for the site, the presence of the seam cannot be discounted.

The Geological Map for the area shows the presence of three adits north of the site (although the historical maps show five adits), at the outcrop of the Ynisarwed (or No. 2 Rhondda) and labels these as Gwyn Colliery.

No mine entries are shown in proximity to the site which may have accessed the suspected underlying seams (Pant Rhyd Y Dwr and Payne's). However, the adjacent map has shown evidence of workings in seams that may represent the Payne's or the Pant Rhyd Y Dwr and although the geological map indicates no workings, or even the presence of these seams, it cannot be discounted that they are not present and have not been worked in the past.

Gwyn Colliery, or as referred to as Gwyn's Colliery in The Collieries of the Swansea Valley General Area (Lawrence 2012) was a small level that was worked for manufacturing and steam coals. It was opened in 1902 when it employed 19 men, then for some reason opening was discontinued during at least 1903/5. It employed 37 men in 1910 when owned by the South Wales Primrose Coal Company and employed 18 men in 1912, and 37 men in 1913 when the manager was J. Standidge. In 1927/8 it employed 7 men and it was transferred to the Tareni Colliery Company in 1928 and no further record was kept.

Reference to the Coal Authority website (CA, 2018) confirms the presence of at least two seams near the TW14 landslide, which correlate to the location of the seams shown on the geological maps and are therefore anticipated to be the Ynisarwed (or No. 2 Rhondda) and the unnamed seam (possibly the Payne's). The CA website also provided the following information:

- Mine entries (five) are present along the outcrop of the Ynisarwed to the north of the TW14 landslide;
- No mine entries are shown for the unnamed seam (Payne's) south of the TW14 landslide area;
- Development high risk areas mirror the outcrops of both seams above, this information suggesting that the CA deems that these seams were worked or were of a size suitable for working;
- Shallow coal mining workings is not indicated below the site, however, underground workings are shown below the site (the Coal Authority defines working less than 30m as shallow) and it is therefore considered that working are at a depth greater than 30m based upon this information; and

- There is no past or present surface mining at the TW14 landslide area.

From the online viewer, it is not clear if the suspected Pant Rhyd Y Dwr seam is located in the area of the site. The information is not conclusive and it is therefore not possible to rule out the possibility of other mine entries or shallow workings within the Pant Rhys Y Dwr or Paynes seam, if present.

It should be appreciated that the Coal Authority records are incomplete, partly because there was no statutory and mandatory requirement on colliery owners to survey and record the extent of mine workings until the Coal Mines Regulation Act of 1872. Therefore, given the potential age of the potential workings, no surveys may ever have been undertaken on them and therefore, the lack of records does not discount the possibility of workings.

2.7.1 Summary of Mining information

The Coal Authority information indicates the presence of five adits that probably worked the Ynisarwed (or No. 2 Rhondda), this information correlates to the aerial photographic interpretation and historical mapping information. Given the location of the adits and our understanding of the geology; workings in the Ynisarwed would not underlie the TW14 slide area and would not impact on stability below the slide area, however, spoil from the adits is located near the northern and western extents of the slide area.

The geological maps and information from the online Coal Authority viewer indicate the possibility of two coal seams to exist below the site, the Pant Rhyd Y Dwr and the Payne's. Both of these seams are reported to be up to 0.91m thick and if worked, may present a subsidence risk to the slide area.

At this stage, a mining report or abandonment plans have not been requested from the Coal Authority and recommendations in this regard are discussed in Section 6.

3 AERIAL PHOTOGRAPHY INTERPRETATION

3.1 Introduction

In order to examine the potential change in morphology of the slope and surrounding land in more detail, and over the course of time; we have obtained aerial photographs held for the site by the Welsh Assembly Government.

A selection of the photographs were stereographical pairs, others were single images and both have been used in this assessment, the below lists the aerial photographs studied in this assessment.

Table 5: Summary of aerial photographs studied

Date	Sortie No.	Type of Photograph and Frame Number	Comments
3 August 1945	3G TUD T19Pt1	Stereo Pair (5075, 5076)	Included enlarged photographs, good detail although 5076 marginally out of focus.
13 April 1947	CPE UK 1997	Aerial Photo (2407)	
22 May 1948	541 RAF 41	Stereo Pair (4173, 4174)	Low detail
27 May 1952	540 RAF 758	Stereo Pair (5032, 5033)	Good detail
14 April 1955	58 RAF 1715	Stereo Pair (302, 303)	
21 April 1960	58 RAF 3506	Aerial Photo	Low detail
14 April 1962	OS 62 014	Stereo Pair (37, 38)	Low detail
16 May 1973	OS 73 175	Stereo Pair (26, 27)	
24 April 1975	OS 75 037	Stereo Pair (106, 107)	Low detail
9 June 1975	OS 75 211	Stereo Pair (149, 150)	
7 April 1978	OS 78 009	Stereo Pair (23, 24)	Low detail
30 May 1982	OS 82 136	Stereo Pair (108, 109)	
30 August 1983	MAFF 218/83	Stereo Pair (71, 72)	Good detail
8 June 1984	MAFF 76/8	Stereo Pair (408, 409)	
14 June 1989	OS 89 279	Stereo Pair (034, 035)	
7 September 1989	OS 89 408	Stereo Pair (61, 62)	
11 April 1994	13 94	Stereo Pair (197, 198)	Low detail
9 April 1997	OS 97 090	Stereo Pair (57, 58)	Good detail

Notes:
1. A selection of the above aerial photographs are provided in Appendix B.
2. The photographs and stereo images are generally black and white until the mid-1990s when colour photographs become widely used.

3.2 Aerial Photography Review

The photographs were reviewed upon a comparison of shape, colour, tone, size and pattern and stereographical analysis was done using a Geoscope stereoscope with 1.2 and 4 times magnification eye piece attachments.

A summary of the salient features identified on the aerial photographs is provided below.

Throughout the historical review, items of interest (mining and springs) have been labelled/itemised to help reference individual features and their change throughout time. For ease of reference, Figure 2 labels the mining (M) and spring (S) locations.

Table 6: Review of Aerial Photographs

Date	Comments
3/8/1945	The landslide area identified by Conway (1980) and in the Geological Sheet is generally similar to an area shown on the aerial photographs with a hummocky and striated appearance compared to its surroundings. This distressed area is considered to be the ground or material that has moved associated with the TW14 landslide, and the limits are generally the same as shown on Figure 4. The distressed area is marginally larger than Conway (1980) indicated and was measured some 265m wide (west-east) by 65m in length (north-south). Within the area of distress, there is a prominent lobe in the central area. A gully is evident in the eastern portion of the slide, associated with stream S1. Adits reference M1, M2, M3, M4 and M5 visible. The M6 spoil mound is not shown. Stream S6 is developed – this is before it is noted on historical maps, historical maps first show it in 1960, based upon this photograph is should be shown on the historical map dated 1948. Stream S7 is present to the southwest of the area of distress. (Note. Image 5076 is out of focus for stereo analysis).
13/4/1947	Aerial photo. No sign of recent movement.
22/5/1948	Photo quality is poor. No obvious signs of any recent movement. There is a darker area of ground near the southern end of the gully for stream S1 which may represent different vegetation or standing water/waterlogged ground.
27/5/1952	The images provide relatively good detail and tone differences are more prominent then previous images. However, there is no evidence of recent movement. Given the clearer quality, the lobes and changes of slope are more clearly defined. Darker tones remain around the southern extent of the disturbed ground by stream S1.
14/4/1955	The photographs are generally of poor quality. Differences in tone generally confirm the outline of the disturbed ground and no obvious signs of recent movement identified.
21/4/1960	Generally poor detail and no obvious signs of movement. Photographs shows the mine and spoil mound, M6 in place.
14/4/1962	Poor detail. There is no sign of obvious recent movement.
16/5/1973	Poor detail. There is no sign of obvious recent movement.
24/4/1975	Poor detail. There is no sign of obvious recent movement.
9/6/1975	Poor detail. There is no sign of obvious recent movement.

Table 6: Review of Aerial Photographs (Cont.)

Date	Comments
7/4/1978	The tone of the ground to the south of the more obvious lobe in the central portion of the disturbed area is darker, potentially indicating the ground to be wetter or with different vegetation. No obvious change in slope morphology.
30/5/1982	No obvious change than previous aerial photographs and no signs of recent movement. The streams look to be well developed and darker tones of ground noted around these. The break lines in slope appear softer and less apparent, not due to change, possibly covered with similar vegetation or degraded over time.
30/8/1983	Good detail shown on aerial photograph. There are more defined breaks of slope at the toe of the main lobe in the central southern area of the landslide, indicating that the toe may have slumped creating a new, more defined break of slope.
8/6/1984	The photo shows good detail, the disturbed area remains hummocky in appearance with mottling of light and dark tones. The 1983 changes to tow breaks in slope are still apparent, as are other slope profiles across the area which are generally similar to original photo studied. Looks as if there has been some stream erosion of soil associated with S1, it is not a separate landslide as there is no run out of material.
14/6/1989	There is no sign of obvious recent movement.
7/9/1989	A triangular area of ground located to the south of the dry-stone wall, but along the northern boundary of the disturbed ground between adit M3 and the easternmost spring, S1, looks to have moved recently. The area has more defined mottling of light and dark tones and has a hummocky appearance than prior images. It may be that this is very slow movement of the landslide or it could also be attributed to anthropogenic reason as ditch clearance works are evident across the study area. The disturbed area measures approximately 45m in width and 25m in length. Elsewhere on the slide, it looks as per previous.
11/4/1994	Colour photograph and poor detail. The area of disturbed ground is brown in colour, the surrounding farmland is green. There is no obvious sign of movement of the main landslide or of the small triangular feature, noted in 1989 photo.
9/4/1997	Good detail and no signs of recent movement.

4 HAZARD ANALYSIS

4.1 Preliminary Geomorphological Mapping and Site Walkover

Following the desk study and aerial photographic assessments, an Engineering Geologist from ESP visited the site on the 16th March 2018 and generated a Preliminary Geomorphological Map for the landslide. The general site observations are discussed in Section 2.2.2.

During the site visit, items of interest identified during the desk study were inspected and all areas of the site were inspected for signs of relatively recent or old movement. The Preliminary Geomorphological Map generated is presented as Figure 4.

The land to the north of the drystone wall, near the northern portion of the landslide system was heavily overgrown and prevented a detailed visual inspection of this area. The mining features, adits and colliery spoil waste were all overgrown and no signs of instability, rock fall etc. at mine entries or slope instability in colliery soil mound was identified.

Drainage ditches presumably excavated by the land owner/farmer showed the presence of rounded gravel and cobbles of sandstone, mudstone and siltstones which are anticipated to be from Glacial Diamicton. A layer of Glacial Diamicton is therefore anticipated across the site, although the extent and thickness are unknown.

Standing water was evident in isolated areas across the disturbed ground, the patch like appearance of reeds and different vegetation also delineated the area of ground that was disturbed.

As discussed in section 2.2.2, standing water was noted at the southern extent of the disturbed area where S1 flows into it and was measured to be approximately 3m wide by 6m in length. The stream S1 was forming a cutting or 'V' shaped depression where it is flowing through the disturbed ground, and the immediately surrounding land was noted unstable, and as Plate 9 shows, trees were falling into the 'V' shaped depression.

The area where the suspected movement occurred, noted in the 1989 aerial photograph was inspected and obvious no large-scale features of a landslide were noted. The ground was similar to that surrounding it, in that is was generally uneven. The ditch that runs near the dry-stone wall was absent in this area, however, the dry-stone wall either side of this area appeared of the same age.

A telegraph pole which is located just to the north of the suspected main scarp was noted to be leaning.

The walkover showed no evidence of recent lobes, scarps or other landslide features that indicate recent movement.

4.2 Conceptual Ground Model

It should be noted that at this stage, no site investigation has been undertaken and the conceptual ground model is based upon a review of the historical maps, aerial photographic interpretation, geological map, other data, the site walkover and geomorphological map.

The ground model is summarised by the following points, and is visually shown in Figure 5:

4.2.1 Site Setting

- The area of study is on the southern flank of Mynydd Allt-y-Grug, the topography of the area slopes downward toward the river Tawe; the valley was glaciated in the last ice age;
- The area of instability is thought to be covered with a layer of Glacial Diamicton over weathered bedrock and bedrock of the Llynfi Member. Strata dips toward the south at an angle of approximately 3° to 5°, which will 'daylight' on the southern and southeastern flank of Mynydd Allt-y-Grug;
- Five coal mine entries are located to the north of the area of instability, and presumably worked the Rhondda No. 2 coal seam, which is not anticipated to underlie the site;
- Spoil from these workings are located near the northern boundary of the site and a spoil mound, M6 appears to have altered the course of streams, S3 and S4, and a stream S6 emerges at some point prior to 1945, although it may have always been present and no reported on maps prior to 1960;
- The coal mining spoil heaps have presumably altered the local hydrogeology and hydrology of the area;
- Two other coal seams, the Pant Rhyd y Dwr and Paynes possibly exist below the site at shallow depths and whilst no evidence of entries have been identified within these seam, workings may be present. The online Coal Authority viewer indicates coal workings below the site, but at this stage it is not known at what depth or seam they worked;
- The geological memoir suggests the roof rock of the Rhondda No. 2 seam is a conglomerate and the underlying Llynfi Member are essentially argillaceous (mudstones, shales, siltstones), with thin bands of sandstone;
- Primary porosity of the Rhondda Member sandstone is likely to be low, but will contain water within joints, fractures and have a higher secondary permeability. The underlying Llynfi Member is considered to be a poor aquifer and fractures/jointing will be less developed than in the overlying sandstone, additionally, joints and fractures may be clay infilled, and the secondary porosity will likely be significantly less;
- Conway (1980) identified three nearby landslides that have a similar geological setting as TW14 and they all showed instability at or below the No. 2 Rhondda coal seam with movement varying from shallow flows to shallow translational slides, all three landslides were classed as dormant;
- Information from other nearby landslides show instability near where spring lines occur and resulted in shallow flows and shallow slumps, typically the landslides were vegetated and dormant, however, activation can occur near active springs with 'strong' flows;

- A series of springs originate upslope of the area of instability, at elevations of between 213m OD and 221m OD. They are considered to arise due to the contrasting permeability and emerge at or below the horizon of the Rhondda No. 2 coal seam. Local to the TW14 landslide, some springs emerge at lower elevations, this likely to be attributed to the impact of mining in the area (M6) and the landslide altering the spring surface expression as it would have altered the shallow hydrogeology;

4.2.2 Landslide Model and Classification

- The landslide was reported in the South Wales Landslip Survey (Conway et al, 1980) as a shallow flow in Llynfi Shale and superficials below the Rhondda No.2 coal seam, between elevations of 198m OD and 213m OD;
- The historical maps do not provide enough detail to confirm when the landslide occurred. The first aerial photo studied, dated 1945 indicated the landslide to be present. There are considered to be two options, either the landslide occurred prior to the first map studied, dated 1876, which is the likely event, or it occurred shortly (years) before 1945, this is on the basis that the emergence of S6 is as a results of ground movement to the north;
- It is considered likely that the landslide occurred sometime after the last glaciation, as a result of high groundwater levels which may have been high at the end of the periglacial climate;
- If the landslide was relatively recent, i.e. shortly (years) before 1945, mining and the alterations of streams/hydrogeology, may have increased porewater pressures and lead to the slip;
- The landslide material is likely to comprise a mixture of Glacial Diamicton (fine-grained soil with gravel, cobbles and boulders) and weathered soils of the underlying bedrock, such as a shale gravel, it may also contain blocks of friable mudstone. The landslide material is therefore likely to be classified as 'debris';
- From our assessment of the form, and likely mechanism, the landslide would be classified as a debris slide. However, given the degraded nature of the slide and assumptions on the ground conditions, this is a hypothesis at this stage;
- The presence of the spring line marginally above the area of instability is likely to form an important factor to the instability. Groundwater is anticipated to be flowing toward the south and forming the spring line between the sandstone of the Rhondda Member and underlying argillaceous rock of the Llynfi Member;
- Water issuing out of the spring lines may have 'softened' the upper horizons of the surface soil (Glacial Diamicton and weathered bedrock) and it is considered that the main trigger to the landslide was an increase in porewater pressure (higher groundwater) at the end of the periglacial period;
- Similar instability, which Conway describes as debris flows and translational slides occur in a similar geological setting as to that of TW14;

- Apart from the main TW14 landslide, the stereographical analysis and site walkover has indicated some evidence of very slow movements with isolated areas of reactivation. Such at the slumping of the toe noted in the 1983 aerial photo and the disturbed area noticed in the 1989 aerial photo. There is also movement near the spring S1;
- Any movement has primarily been noted on the footprint of the landslide and no evidence of the landslide moving further down gradient has been identified in the historical maps, aerial photos or walkover;
- Although the back tilted telegraph pole is thought to be outside of the footprint of the landslide, it has moved due to its likely location of bearing near the backscarp and suggests instability;

4.2.3 Other Considerations to Ground Model

- Streams are running through the slipped mass and there may be a perched groundwater table within the disturbed mass; and
- areas of soft ground/surface water are present across much of the slipped mass.

It may be prudent to confirm parts of the above ground model through a ground investigation.

4.3 Hazard Identification

4.3.1 Introduction

The Ground Model indicates that a single debris slide has occurred in the study area and it is broadly located in the reported area of the TW14 landslide, the mapped extents of this landslide are shown in Figure 4.

The landslide material is likely to comprise debris, of Glacial Diamicton and variable weathered bedrock.

The landslide measures approximately 265m in width and 65m in length and has an area of approximately 11,850m^2. The debris slide was degraded and in parts may have been altered by man (ditches), however, it was visually estimated to be 2m to 3m thick at the toe (although varies) and possibly approximately 1m thick near the head, although these are estimated from visual observations. Using an estimated and generalise thickness of 2m across its entire area, the volume of displaced material is 23,700m^3.

As discussed in Section 4.2.2, the single landslide is considered to have occurred after the last glaciation, which ended some 11,700 years ago. The landslide was likely triggered by a high groundwater level as the periglacial climate was ending.

There is evidence of slow ongoing movement of the landslide within the aerial photos, indicated by the more visible hummocky ground and different tone changes between aerial photos. However, the differences are always slight, and no large-scale movement is noted. The movement has been observed to be within the footprint of the landslide and no movement of material has been noted to slide or flow out (detach) of the landslide area, even around the streams.

Some erosion and associated instability is occurring near to streams, notably S1 in the east. However, this is again limited to the landslide and aerial photos show this area to have been modified by man in the past. With the exception to the small movements noted, there is no evidence of large scale movements.

A brief review of nearby landslides set in a similar geological context and similar mechanism were all reported as dormant and not active, with the exception of some activity near 'strong' springs. The ditches and springs at the study area appear well developed and generally small, nominally 0.5m in width and are considered too small to initiate a larger scale failure than already being noted (small erosion at stream sides).

It is only possible to estimate the movement velocity of the original landslide and based upon the current morphology and the landslide class it is likely that is moved at a moderate velocity, i.e. between $5x10^{-3}$ and $5x10^{-1}$ mm/s, or 1.6m/year to 13m/month which is based upon WP/WLI (1995) and Cruden and Varnes (1996). Using the same classification system, the movement noted since 1945 in the aerial photos, is considered to be very slow, i.e. between $5x10^{-7}$ and $5x10^{-5}$.

4.3.2 Hazard 1 - Reactivation or New Debris Slide Similar to Original Failure

The location of the TW14 landslide is has been mapped (Figure 4) and has a downslope length of around 65m and an assumed thickness of 2m across its entire area. The material is likely to be a mixture of coarse and fine-grained soils and the landslide has been classified as a Debris Slide. Debris Slides typically move at moderate velocities and the ground model suggests that the trigger event was a high groundwater level at the end of the periglacial conditions, thus this event is inconceivable to reoccur in our current climate.

4.3.3 Hazard 2 - Slow Soil movement of Debris Slide (within TW14)

Evidence of very slow movement (gradual changes in slope morphology) is occurring in the footprint of TW14 that it is likely to be restricted to the depth of the landslide material. This is considered to be very slow movement of the Debris Slide and could be occurring as a result to significant (circa 10year) rainfall events.

4.3.4 Hazard 3 - Debris Avalanche following Extreme Weather Event

Some localised material from TW14, around S1 for example, could become detached following an extreme weather event (say 1000 year event) and form a localised Debris Avalanche, which would have a very rapid to extremely rapid velocity. There is not considered to be any channel for confinement, and as only part of the TW14 Landslide would be become detached, the debris mobilised will be of limited thickness. There is no evidence of such occurrences in the landslides with a similar geological setting discussed in Section 2.1.2 and no morphological features of this type in the study area. It is considered such event might occur under very adverse circumstances.

5 QUALITATIVE RISK ASSESSMENT

5.1 Introduction

This section considers the probability and severity of the identified hazard having an adverse effect to health of people, property or the environment.

For this site and preliminary assessment, there is not considered to be a robust and widely used assessment criteria that can simply be adopted to undertake a 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 the risk to property only.

The modified descriptions and risk rankings used in this assessment are presented below. Table 7 provides a qualitative measure of likelihood and Table 8 present a qualitative measure of consequences.

Table 7: Qualitative Measures of Likelihood

Approx. Annual Probability		**Implied Indicative** Landslide Recurrence **Interval (years)**		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}		10		The event is expected to occur ever the design life	Almost Certain	A
	$5x10^{-2}$		20			
10^{-2}		100		The event will probably occur under adverse conditions over the design life	Likely	B
	$5x10^{-3}$		200			
10^{-3}		1,000		The event could occur under adverse conditions over the design life	Possible	C
	$5x10^{-4}$		2,000			
10^{-4}		10,000		The event might occur under very adverse circumstances over the design life	Unlikely	D
	$5x10^{-5}$		20,000			
10^{-5}		100,000		The event is conceivable but only under exceptional circumstances over the design life.	Rare	E
	$5x10^{-6}$		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 8: 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 considered risk to property.		

The associated levels from Table 7 and 8 are then used in Table 9 to provide a qualitative risk ranking and Table 10 provides example implications for each risk ranking.

Table 9: 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 10: 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.	

The qualitative analysis has been undertaken using the information gained from this assessment, 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.

Whilst the historical maps have provided key information on the streams and mining features around the study area, they do not show any movement of the landslide, or show the form of the landslide which is likely to have been too small, or insignificant to show. Therefore, the assessment is largely based upon the period of time covered by the aerial photographs, from 1945 to the present day. The above assumption should thus provide a more conservative assessment.

5.2 Elements at Risk

The TW14 landslide is located within an agricultural setting and surrounded by fields, that predominantly provides rough grazing to farm animals. The information obtained from this assessment indicates TW14 to have a run out length of 65m, landslides in a similar geological setting have a maximum run out distance of 150m (Section 2.1.2).

The nearest property down slope of the landslide is a single farm building (Pentwyn) which is some 250m to the south. Beyond this, the next nearest property is some 340m to the south.

A footpath passes to the south of the landslide and at its closest point is approximately 140m to the south. This footpath was used to gain access to the landslide for the walkover and although it is not possible to accurately state its usage without counting

walkers, it was noted to be overgrown and generally undefined, indicating that it is not a very busy footpath.

5.3 Risk Assessment

The Hazard Assessment (Section 5.1) indicates that the landslide is considered essentially self-contained. On this basis and using the assessment criteria proposed by Jones and Lee (1994), the TW14 landslide would be classified as dormant, as the landslide remains stable under most conditions but may be reactivated in part, or as a whole by extreme conditions. Similarly, Cruden and Varnes (1996) would classify TW14 as dormant, which they define as an inactive landslide that can be reactivated.

The Hazard Identification (Section 4.3) indicated three hazard types and these are discussed further below, using the qualitative terminology presented in Tables 6 to 9.

5.3.1 Hazard 1 - Reactivation or New Debris Slide Similar to Original Failure

Reactivation of the TW14 Debris Slide or generation of a new slide is considered barely credible, as the trigger event is considered to be high ground water conditions associated with the end of a periglacial period. Furthermore, evidence suggests that such a failure would move less than 100m downslope, with the maximum movement of 150m noted in similar condition, given that the nearest property is some 250m, this movement is not considered to represent a hazard to property.

If for some unforeseeable reason, the debris slide was to travel to the nearest property, it may cause limited to moderate damage to the property, and based on this consequence, should it occur, this would represent a very low risk.

5.3.2 Hazard 2 - Slow Soil Movement of Debris Slide (within TW14)

Very slow movements are occurring within the disturbed material of TW14, thus the likelihood of this occurring is almost certain. However, such movement does not represent a hazard to the identified elements at risk, and there is thus no perceivable risk.

5.3.3 Hazard 3 - Debris Avalanche following Extreme Weather Event

Some localised material from TW14 could form a debris avalanche following an extreme weather event. Such an event might occur under very adverse circumstances and is thus considered to be unlikely. The debris avalanche could potentially damage elements at risk (Pentwyn Farm) and on the basis of limited damage, or a minor consequence, a low risk is considered for this assessment.

5.3.4 Further Discussion

As discussed in Section 5.1, the above risk assessment only considers the risk to property. Although the following is not based upon any recommended risk assessment framework, as no suitable qualitative framework is known, we have attempted to qualify risk to walkers from the three hazards who will be using the path, which is approximately 140m to the south of TW14.

On the assumption that the walkers stay on the public footpath, Hazard Type 1 and 2 represent a low risk or no risk respectively. This is based upon several assumptions, such as the run-out distance being less than 140m, trigger of TW14 is high groundwater under different climatic conditions and a low use of the footpath.

Hazard Type 3 could potential cause a fatality, however, such an occurrence is considered rare or barely credible, as the footpath appears to be less well used, it would probably be less well used in winter months, when such an event would likely occur, the avalanche would be relatively narrow, and walkers may be able to hear/see it coming and avoid it. On such assumptions, the likely risk to walkers is considered as low.

As discussed in section 5.3, the above assessment is assuming that the landslide is not altered in any way through farming practices or developed upon, or no further down slope development occurs.

6 CONCLUSION AND RECOMMENDATIONS

The qualitative assessment has indicated that the Cilmaengwyn landslide (TW14) represents a low risk to the nearest property for one of three hazard types identified.

The assessment has had to make several assumptions on the ground model and some signs of instability have been noted (telegraph pole) and its possible that the relatively recent mining legacy of the site has altered the hydrogeology and hydrology of the area. To provide more information for the ground model, and ascertain the groundwater conditions, it would be prudent to undertake some basic investigation. On the basis of a low risk rating, some investigation is in line with the AGS (2007) recommendations. It may also be prudent to assess the rates of movement that is occurring.

We would therefore recommend a scope of limited investigation broadly in line with the following:

- Consideration could be given to a Coal Mining Risk Assessment for completeness, however, it is not considered essential at this current time;
- Limited investigation works comprising trial pitting and boreholes to confirm the ground model and identify any groundwater with a period of groundwater monitoring; and
- Topographic survey with monitoring points such that return visits could be carried out check the rate of movement across the landslide area.

7 REFERENCES

AUSTRALIAN GEOMECHANICS SOCIETY. 2007 Practice Note Guidelines for Landslide Risk Management 2007. Volume 42 No 1 March 2007.

BRITISH GEOLOGICAL SURVEY (BGS). 2018. Website accessed April 2018.

BRITISH STANDARDS INSTITUTION (BSI). 2015. Code of Practice for Ground Investigation. BS5930:2015. HMSO, London.

CONWAY B W, FORSTER A, NORTHMORE K J, and BARCLAY W J. 1980. South Wales Coalfield Landslip Survey. Institute of Geological Sciences, London.

CRUDEN, D.M., VARNES, D.J., 1996. Landslide Types and Processes, Transportation Research Board, U.S. National Academy of Sciences, Special Report, 247:36-75.

FELL, R., CORMNINAS. J., BONNARD, C., SAVAGE, W.Z., CASCINI, L., LEROI, E. 2008. Guidelines for landslide susceptibility, hazard and risk zoning for land-use planning Commentary. Engineering Geology. 102 (58-98)

HUNGR, O., PICARELLI, L., 2014. The Varnes classification of landslides types, an update.

LAWRENCE, R. 2012a. The Collieries of the Swansea Valley General Area. *The South Wales Coalfield Series Book One Hundred.* Ray Lawrence, Blackwood.

LAWRENCE, R. 2012b. The Collieries of the Swansea City General Area. Ray Lawrence, Blackwood.

LEE, M. and JONES, D.K.C. 2014. Landslide Risk Assessment. Institute of Civil Engineers, London.

STRAHAN A. 1907. The Geology of the South Wales Coalfield, Part VIII, The Country around Swansea. Memoirs of the Geological Survey England and Wales, An Account of the Region Comprised in Sheet 247 of the Map. HMSO.

STRAHAN A. and CANTRILL T C. 1912. The Geology of the South Wales Coalfield, Part III, The Country around Cardiff. Second Edition. Memoir of the Geological Survey, England and Wales. Explanation of Sheet 263. HMSO.

WILSON D, DAVIES J R, FLETCHER C J N and SMITH M. 1990. The Geology of the South Wales Coalfield, Part VI, The Country around Bridgend. Memoir of the British Geological Survey, Sheet 261 and 262 (England and Wales).