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Pantteg and Godre'r-Graig Landslips
Slope Stability Review

December 2013

Report No: B15974EX / 12858 / R5095

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Contents

1 Introduction

1.1 Scope of Report

This report has been compiled at the request of Neath Port Talbot County Borough Council (NPT CBC), to update the existing hazard and risk assessment of the landslip areas known as Pantteg and Godre'r Graig.

The report takes account of the existing historical reports and investigations, combined with a number of site inspections made during 2013.

From the information gained an updated Hazard and Risk map of the area has been produced. In addition, a number of specific concerns raised by the client in respect to the stability of the site have been responded to, with recommendations.

1.2 Background

There is an ongoing history of instability at two landslips known as Pantteg and Godre'r-Graig, which are located to the south-west of the town of Ystalyfera in the Swansea valley. The extent of the landslip areas were identified by the British Geological Survey (BGS) on their published survey. The BGS identified the land-slipping as ancient, but recent recorded activity of the slips has been ongoing over the last 60 years. BGS mapping gives a generalised extent to the area of landslip, but it is noted that instability may locally extend beyond the mapped boundary.

The latest instability occurred at Christmas 2012, and following this event Jacobs UK Ltd was requested to update the previous Hazard and Risk assessment of the area, which was last carried out in 1997.

Ground conditions and instability at the site are complex and operate on a range of scales. Rates of movement vary across the site and movement can be triggered by a variety of influences, the intensity of which also varies across the site. The assessments of stability hazard and associated risk included within this report are qualitative, based upon site observation in conjunction with interrogation of the available historic investigation. The assessment should be reviewed regularly in light of developing conditions at the site and at least annually to observe the effects of seasonal rainfall and associated groundwater conditions.

2 Existing Information

2.1 Existing Reports

There has been a recorded history of ongoing active instability of both the Pantteg and Godre'r Graig landslips since 1946, although it is noted that there was likely to be unrecorded movements prior to this date. This has resulted in the production of a number of previous reports, as follows:

- *Godre'r Graig & Pantteg Landslides, Report on Hazard Mapping* July 1987 [ref.1]
- *Pantteg Landslide, Report on Ground Investigation* December 1989 [ref.2]
- *Pantteg and Godre'r Graig Landslide Area, Report on Assessment of Landslide Hazard* February 1998 [ref.3]

The 1987 report includes a summary of instability and ground movements from 1946 to 1987, and a summary of the known geology at the time. This was updated by the 1989 report which included information from site specific ground investigation works within the Pantteg landslide area, resulting in the production of some geological cross sections of the site; these are included within Appendix D of this Report. The logs of the trial pits undertaken have been included in Appendix C of this report.

The 1987 and 1989 reports produced the original Hazard and Risk assessment plans. The methodology used is set out and discussed in Section 5.

The initial reports were requested by the Lliw Valley Borough Council, which operated as the local authority from 1974 to 1996. The current client, NPT CBC took over responsibility for the area in 1996, and carried out a review of the Landslide Hazard in 1997, resulting in the revised Hazard and Risk Zonation Map, and the accompanying Report, which was published in 1998.

2.2 Published Data

In addition to the existing reports, the published information sources listed below have also been accessed in the compilation of this review:

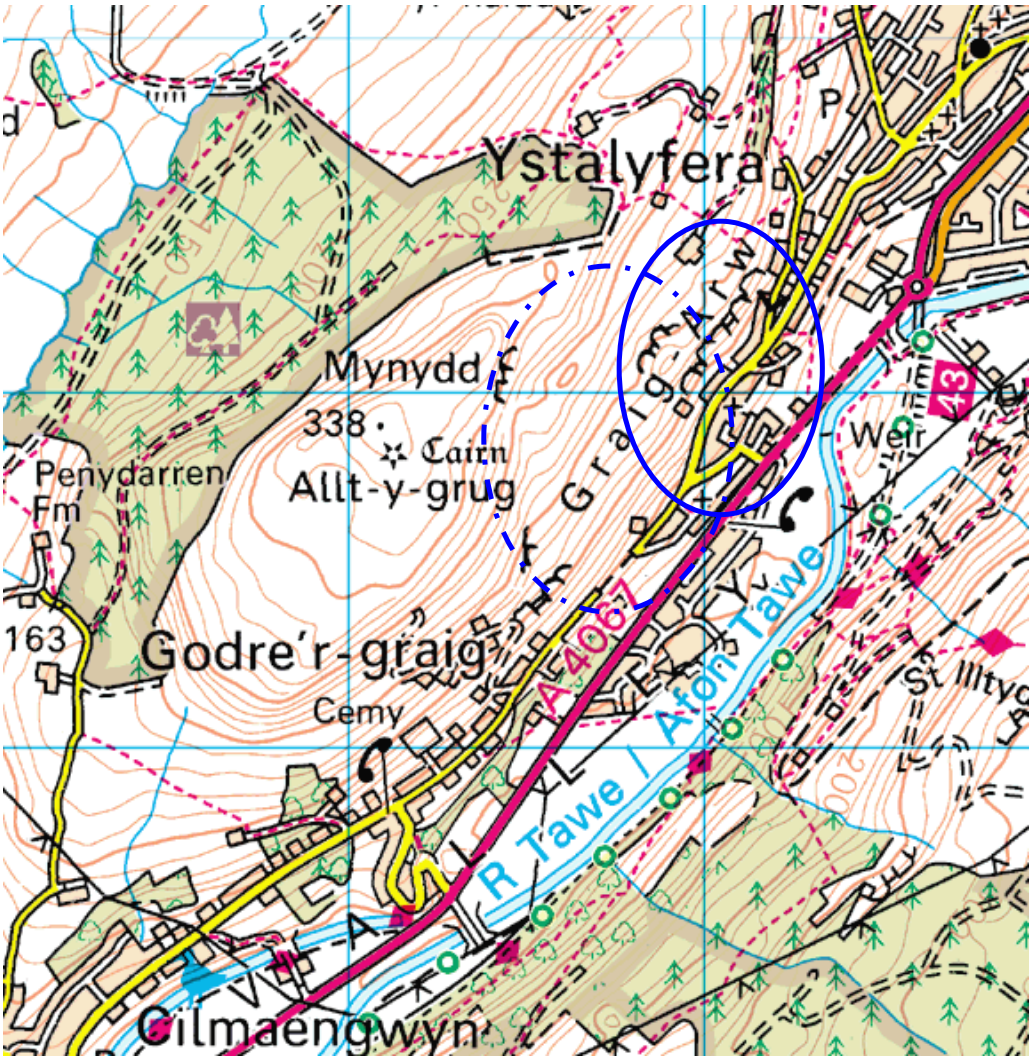
- Online Geological mapping [ref.4].
- Records of historical boreholes in the area [ref.5].

Historical borehole data was extracted from the Open Source resource provided by the British Geological Survey. There are a number of trial hole records related to the site; the Logs have been inspected, and are presented in Appendix C.

3 Site Description

3.1 Geographical Location

The site area is extensive, and is located on the north side of the Swansea valley to the south-west of the village of Ystalyfera.



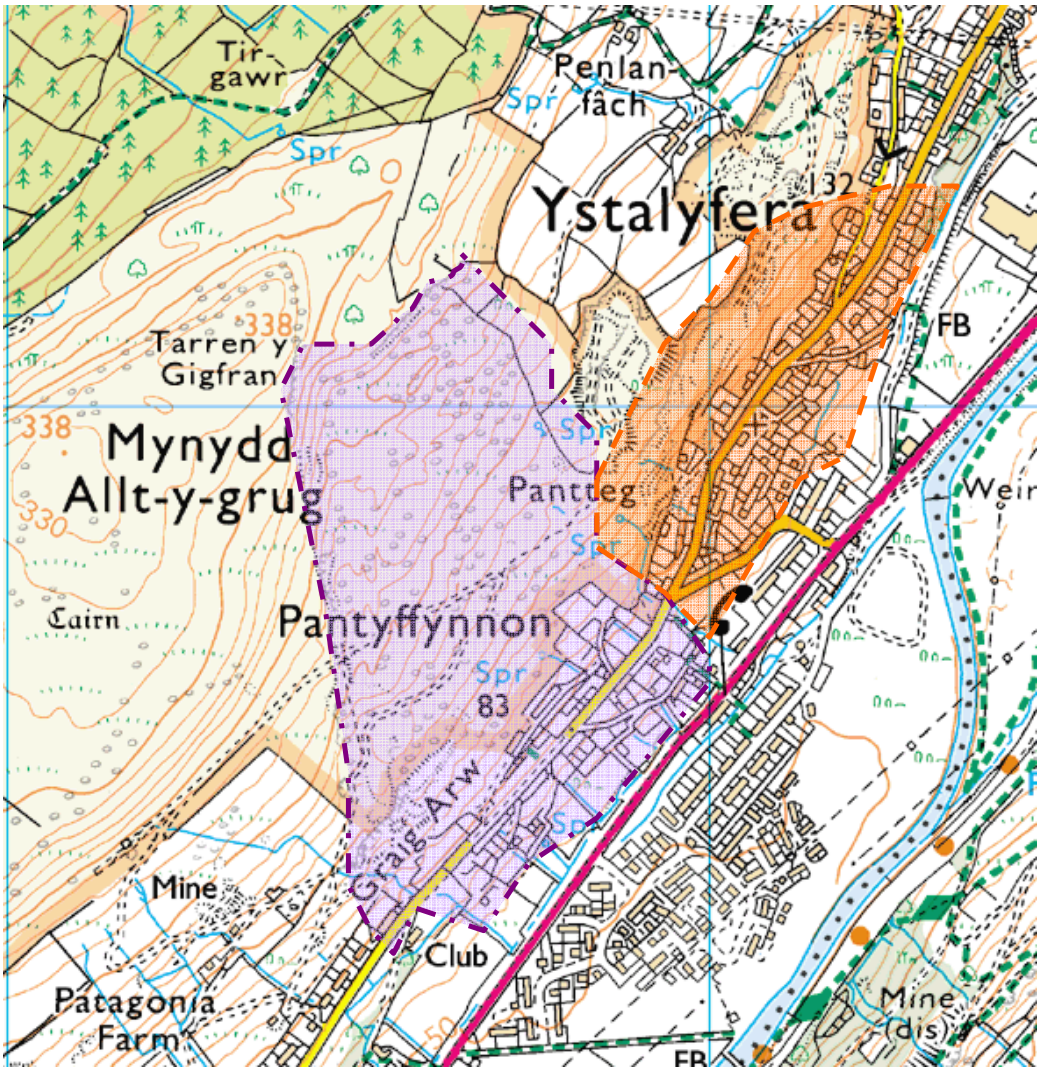
Extract from the 1:50,000 scale Ordnance Survey Map showing the approximate locations of the Pantteg landslip (blue solid oval) and Godre'r Graig landslip (chain dotted blue oval).

3.2 Site Description

The two areas are part of a large scale, complex, interlinked slip system. The full extent of the area under consideration extends from the valley floor to the west of the A4067 valley road, to the summit of Mynydd Allt-y-grug, a distance of approximately 750m, and along the valley from the Club at Graig Arw for approximately 1100m to the south end of Ystalyfera village. The vertical extent is

from 60 metres Above Ordnance Datum (mAOD) in the valley to 300mAOD on Mynydd Allt-y-grug.

For the purposes of this report, the boundary between the two landslip areas is taken to be at the Junction of Graig Road, Pantteg and Church Road, extending south-east (downslope) along the line of the stream, and north-west (upslope) to the entrance to the sandstone quarry above the location of the former Penygraig House. The actual boundary will be more complex, and there is likely to be some interaction between the two landslip areas.



Extract from the 1:25,000 scale Ordnance Survey Map showing the approximate extents of the Pantteg (orange shading) and Godre'r Graig (purple shading) landslips adopted in this assessment.

3.3 Topography

The site is located on the north-west side of the Swansea valley that runs from north-east to south-west, containing the south-westward flowing River/Afon Tawe.

Vertically, the site extends from the valley floor at the edge of the floodplain, to high on the upper slopes of Mynydd Allt-y-grug.

The foot of the slope is roughly analogous to the current A4067 road, which was constructed along the alignment of the old Swansea Canal. From this level there is a rise towards the line of the 'old' valley road (Graig Road / Cyfyng Road), which steepens as the upper road is neared.

The valley side above the 'old' road is generally steeper than 1v:2h, and extends up to an elevation of about 150mAOD, after which the slope slackens off.

The Pantteg Landslip area (to the north) terminates at a line of cliffs approximately 100-120m from the road, the foot of the cliffs being at approximately 170mAOD.

The Godre'r Graig landslip area extends further west, terminating at a steep scarp that ascends the side of Mynydd Allt-y-grug.

The Ordnance Survey 1:25,000 scale map indicates the presence of a number of springs within the area. Site knowledge indicates that some of these are actually old coal mine entrances and the 'springs' are drainage of minewater from the adits.

3.4 Site History

The hillside above the villages of Pantyffynnon and Pantteg exhibits evidence of historical coal mining, and quarrying of the sandstone which it is believed was used as a local supply of building materials. The large scale base plan used to produce the 1989 Hazard and Risk map indicates the presence of levels (adits) and the sandstone quarry of Cwar Pen-y-graig-arw.

The road that runs the length of the site was the original main road up the valley (the A4068). Ongoing instability of the valley side at Pantyffynnon and Pantteg resulted in the diversion of the road to run along a new alignment on the valley floor, following the approximate line of the disused Swansea Canal; this opened in 1965.

The villages at Pantteg and Pantyffynnon were constructed on the steep valley sides above the valley floor, which are interpreted to represent the lower slopes of an ancient landslide. The instability of the landslips re-activated in 1946. Subsequent movements have led to the destruction of most of Pantyffynnon, and houses not demolished by ground movements have generally been abandoned; the road through the centre of the village has been blocked off to deny vehicle use. The few remaining habitable houses are all below the old road.

The village of Pantteg has also been affected by ground movements, and the majority of the properties to the north-west of the road have been abandoned and or demolished due to ground movements. There are a few remaining, extending from the Chapel to Graig y Merched.

The areas to the east (ie down hill) of the old valley road are known to consist of a fan of colluvial material – material that has failed from the hillside above and come to rest on the lower slopes and valley floor. Much of this material has been built upon, the properties primarily being newer dwellings.

There is currently no mining or quarrying on-going. Access to old adits and the quarry is heavily overgrown, and there is no evidence of any recent workings.

3.5 Site Instability

Ground conditions and instability at the site are complex and operate on a range of scales. Rates of movement vary across the site and movement can be triggered by a variety of influences, the intensity of which also varies across the site.

A cross section through the Pantteg landslip was produced by Halcrow [ref.2], which is presented in Appendix D, along with the 1989 mapping of the Pantteg area. This identifies the landslip at Panteg as being split into upper and lower systems, as follows:

Upper Landslide system
The upper limit of the Pantteg landslides is the cliff face caused by the outcrop of the Llynfi Rock sandstone. As with all of the strata on the hillside, there is a dip out of the slope, allowing for the sandstone to fail in planar sliding, as evidenced by the screes at the foot of the cliff. The cliffs themselves are generally near vertical.

The resulting failed material falls onto the underlying siltstone layer, which forms a downhill sloping terrace below the sandstone cliffs. Currently this is covered in vegetation, suggesting that there have not been any recent falls. The landforms on the terrace also suggest the presence of rotational movements affecting the underlying siltstone units.

Historical ground investigation works suggest that the base of the failure is controlled by the presence of the Lower Pinchin coal seam, and effectively the failed material that forms the terrace is founded on this base plane.

Over time the volume of material on the terrace increases, and there is a downslope movement, probably assisted by groundwater emerging along the basal coal seam, causing the material to descend downslope into the top of the lower system.

Lower landslide system
The lower landslide system extends downslope of the outcrop of the Lower Pinchin coal seam, the backscarp being within a layer of competent siltstone, which appears to form a steep slope above a narrow terrace. The terrace appears to be analogous to the outcrop of the claystones containing the Upper Cwmgorse Marine Band. Below the terrace a steep slope drops down to the level of the old valley road (Pantteg / Cyfyng Road).

Failures in the lower system appear to be a combination of shallow rotational movements and superficial deposits sliding off of the underlying bedrock. Failures will be driven by the presence of groundwater, in this case emerging from the Thin Coal seam below the Cwmgorse Marine Band, surface water from the hillslope above and increased loading caused by descent of material from the upper system.

Colluvial area
Below the old road, there is evidence that the village is built upon colluvial deposits, ie material that has failed on the slope above, and come to rest on the lower slopes above the valley floor. Consequently this area is likely to be marginally stable.

3.5.1 December 2012 Instability

It is understood from the client that significant ground movement was observed to the east and north-east of Penygraig house in the two years prior to the December 2012 event. This coincided with severe weather experienced in the area over two winters in addition to the wet summer of 2012.

The most recent significant instability event occurred on 22 December 2012, and affected an area of Pantteg between Penygraig House and Pantteg Chapel. A landslip occurred that blocked the highway at Pantteg Chapel, and partially blocked the road opposite 49 Pantteg. Access to Penygraig house was severed. See Plates A-1 to A-4.

This failure was restricted to the Lower Landslide system, as described above.

The site was visited and inspected by Jacobs' geotechnical engineers in early January 2013. They undertook a visual assessment of the failure and provided recommendations to the client regarding site safety and remedial works to allow the reopening of the highway. These are documented in separate correspondence [refs 6-8].

The remedial works consisted of clearing the failed material from the highway and slope, extending up to the existing ledge, the works being limited to what could safely be achieved with locally available plant. The key part of the works was to remove the superficial material that exhibited failure, by excavating back to rockhead where possible. Only material that had failed in 2012 and in the two years previously was removed. This material was removed from site, and allowed the creation of a drainage ditch and berm at the foot of the slope, and a run-out area opposite the chapel. The works also resulted in the demolition of Penygraig House on safety grounds, following the discovery of cracks uphill of the house, distress to the property, and the proximity of the newly re-graded slope.

The extent of works carried out can be seen in Plates A-5, A-6, A7 and A-11

The failure had also resulted in the partial destruction of the mine drainage system (pipework) in the vicinity of Penygraig House – this was repaired and reinstated.

The recommended remedial works were not intended to prevent any future slope failure, but to remove the immediate risk from the unstable material and make the site safer and to reduce the risks that might be associated with any further failure immediately upslope of the road.

The cause of the failure is difficult to apportion accurately, but is likely to include contributions from: naturally oversteep slopes, low strength superficial materials, leakage from the mine drainage system, collapse of old mine workings, preferential

groundwater flows from the coal seam and extended periods of heavy rainfall through 2012.

3.6 Site Inspections

Site inspections were carried out by Jacobs from January to June 2013.

The inspections in January were to assess the recent instability and advise on measures to make the slope safe. Following this, there were regular inspections during the execution of the remedial works.

A more extensive site inspection in June covered the general area of both the Pantteg and Godre'r Graig landslips, and was undertaken to enable updating of the hazard and risk mapping of the area. The inspection was undertaken by a Jacobs engineer, accompanied by the client's engineer throughout the inspection.

It is understood that the client's engineer continues to undertake regular visual monitoring inspections of the slope at Pantteg, especially above and adjacent to the area of the 2012 failure.

3.6.1 Visual Inspection June 2013: Introduction

A site visit was carried out by a Jacobs' geotechnical engineer on 11 and 12 June 2012, to examine the full landslip area, in the company of the Client's engineer. The Pantteg area was inspected on 11 June, and the Godre'r-graig area on 12 June.

The purpose was to inspect the following items:

- Nature and pattern of the evidence of distress to ground.
- Exposures of the geology.
- Slope angles, both natural and artificial.
- Watercourses: sources and destination.
- Natural and artificial drainage.
- Remains and evidence of the historical mining within the boundaries of the landslips.

The 'uphill' boundaries of the landslip areas were defined by the scarp features evident on the ground – usually in the form of distinct cliffs to the rear of the Pantteg slip, and to the western edge of the Godre'r Graig slide. These boundaries are defined by the BGS mapping and previous mapping exercises [refs 1 to 4]. The north-eastern boundary of movement can be seen on Graig y Merched, but not on the Cyfyng Road further downslope. The south-western limit is defined by the line of the backscarp.

In general there was no inspection to the south-east of the valley old road (Graig Road / Pantteg / Cyfyng Road), with the exception of the area around Owens Lane. Much of this land is in private ownership and it was not possible to carry out inspections of the landforms. Jacobs have not been informed of any ongoing history of ground movements or distress to structures in this area. However, stability may be marginal, and it may be prudent to arrange inspection of this area.

The assessment takes account of features readily observable at the time of the inspection, and may not characterise all aspects of the slope morphology. The inspection was limited to areas that could be safely accessed; various parts of the sites were too steep or dangerous to access, and consequently it is possible that additional evidence of ground movement may be present that could not be observed. Similarly, as the inspection was carried out in the summer months, when vegetation growth is at the greatest, then evidence of ground movement may have been concealed by seasonal growth.

The observations are relevant to one point in time – evidence of movement that has appeared subsequently to the inspection will not have been observed. The interval between updates to the hazard / risk map are such that changes in the nature of defects are difficult to establish.

The site inspection could only observe surface features. Understanding of subsurface details has come from the reports of previous ground investigations and published sources only.

3.6.2 Visual Inspection 11 & 12 June 2013

This section should be read in conjunction with drawing B15974EX/12825/R5095/1.

The walk over on 11 June covered the area of the Pantteg landslip, starting with the recently re-graded slope, and then extending to the north and east of the slip area, where the tension cracks that were forming at the top of the steep slope could be inspected and traced.

The regrading of the slope had been undertaken by contractors under the direction of NPT CBC engineers. The loose material was removed and the slope re-graded to a relatively consistent profile, the top of the slope tying in to an apparently stable 'rock' ledge.

Penygraig House was demolished on safety grounds, based upon the presence of cracking 'uphill' of the building, distress to the property, and the proximity to the exposed edge of the reprofiled slope.

Visual evidence indicated that the ledge that had been left in-situ following the December 2012 failure could be unstable; a large Ash tree was leaning backwards, suggesting a rotational failure of the slope was in progress. The ledge follows the approximate alignment of the outcrop of the Upper Cwmgorse Marine Band. Adits into the outcrop were identified further north (above Graig-y-Merched), and an additional adit – previously unrecorded – was exposed opposite Pantteg Chapel.

Photographs of the re-grading works are presented in Appendix A, Plates A-5 to A-7 and A-11.

There were open fissures in the ground above the ledge, indicating downslope movement on the steep slope, which extended for a length of about 100m along the slope, opposite Pantteg Chapel and Hall; see Plates A-8 to A-10 in Appendix A. It appears that the fissuring extends beyond the northern extent of the recent failure and to the rear of numbers 21, 23 and 25 Pantteg, roughly corresponding to the

extent of the High Hazard area on the 1997 map. This can be seen on Plate B-6 in Appendix B. The fissures appear to mark the boundary between the Upper and Lower landslide systems.

The fissured area was traversed by a post and mesh 'stockproof' fence. Due to the extensional ground movements, the mesh had been pulled off of the wooden posts and was tautly stretched over the convex curve of the hillside.

Further visual evidence of distress was seen on the Graig-y-Merched road, specifically in the area above the retaining wall on the north-west side of the Cyfyng Road. There was some distress to the carriageway, but the obvious evidence was in relation to the overhead power and telecoms cables; these had become tightly stretched between the poles, so much so that one pole was leaning significantly away from the vertical. This is shown in Plate A-13.

The retaining wall on the Cyfyng Road showed no obvious signs of distress, as shown in Plate A-14.

Where possible, the mine drainage systems installed on the hillside were inspected, the findings are detailed in section 4.5. Access for inspection was limited due to the growth and density of vegetation. In fact, inspection of the entire area was hindered by the presence of high/dense vegetation, much of which could not be penetrated on foot. This suggests that a further inspection during the winter, when the vegetation has died back, may be advantageous.

Overview images of the Pantteg Landslip area are presented on Plates B-4 to B6 in Appendix B.

The Godre'r-graig landslip area was inspected on 12 June. No evidence of active slipping was observed, although landforms on the slope above the Graig Road were indicative of a history of ground movement. These consisted of lobate forms indicative of rotational failures and/or earth flows.

Overview images of the Godre'r Graig Landslip area are presented on Plates B-1 to B-3 in Appendix B.

3.6.3 Client Updates

During the site walkover it was suggested that the client arrange to take some overall photographs of the site, if possible, from the mountainside opposite. This would allow an overview of the entire site to be inspected from a high perspective. A series of images have subsequently been taken by the client, which are presented in Appendix B.

The client's engineer is continuing to carry out regular visits to visually inspect the site and make his own assessment of the rate of ground movement, and potentially identify new areas of distress.

A client inspection the on 7 August 2013, following heavy rain, revealed movement of the ledge opposite the chapel at Pantteg, as anticipated during the walk over. Comparison photographs are presented in Appendix A (Plates A-9 and A-10), which show the failure of the vegetation grown ledge at the top of the regraded slope. The

failure appears to be relatively small, only affecting the top 4 to 5m (approximately) of the regraded slope.

4 Geology

4.1 Solid Geology

The underlying geology of both the Godre'r Graig and Pantteg slip areas is the same; the solid geology of the area is indicated on the geological map of the area, and is stratified as follows:

Table 4-A Solid Geology of the Godre'r Graig and Pantteg Landslips

	Member	*Named Horizons*	*Comments*
Upper Coal Measures or "Pennant Measures"	Rhondda Member	Sandstone	
		No.2 Rhondda	Coal Seam (Mined)
	Llynfi Member	Sandstones / Siltstones / Claystones	
		Upper Pinchin	Coal Seam (Mined)
		Sandstones / Siltstones / Claystones	
		Upper Welsh	Coal Seam (Mined)
		Sandstones / Siltstones / Claystones	
		Lynfi Rock	Sandstone (Quarried)
		Sandstones / Siltstones / Claystones	
		Lower Pinchin	Coal Seam (Mined)
		Siltstone	
-M-M-M-M-M-	Boundary Horizon	Lower Cwmgorse Marine Band	
Middle Coal Measures		Mudstone	
		Thin Coal	Adit found opposite Pantteg Chapel
		Siltstone	
		Thin Coals	
		Lower Welsh	Coal Seam (Mined off site)
		Siltstone	

Although not detailed on the geological maps, but many coal seams are underlain by a layer of clay known as 'fireclay' or 'seat-earth', and it is possible that this weak layer is acting as the plane of weakness that is associated with the coal seams.

A geological plan of the Pantteg area produced as part of the Halcrow 1989 [ref.2] report, along with an interpreted cross section, is presented in Appendix D. The published geological map of the area indicates a dip of the strata towards the south, which results in the effective dip of the strata being out of the slope at both Pantteg and Godre'r Graig.

The lowermost strata subject to the landslips at the site are the Middle Coal Measures, which are generally entirely mantled by landslipped materials from above. The stratum consists of mudstones and siltstones, with thin coal measures. There is no record of the thin coal seams being mined from within the boundaries of the site, although they are known to have been mined elsewhere in the district. Unrecorded workings may be present.

The boundary at the top of the Middle Coal Measures is identified as the Upper Cwmgorse Marine Band, which is indicated in this area by a layer of 'claystone'. The outcrop is roughly analogous to the ledge that was made use of by the path that extended east from Pantyffynnon, past Penygraig House, although it becomes difficult to identify to the east of Pantteg Chapel.

This ledge was left following the remedial works in early 2013, and can be seen in Plate A-11 (in Appendix A). It featured a previously unrecorded entrance to a mine opposite Pantteg Chapel hall. It is presumed that this was an adit to gain access to the Thin Coal seam at the base of the claystone.

The strata above the claystone are part of the Llynfi Member, which form the lowest unit of the Upper Coal Measures or "Pennant Measures", and generally consist of siltstones and sandstones. The Lower Pinchin coal seam is found in the area, and boreholes carried out for the 1989 report encountered three leaves of the Lower Pinchin Seam, the upper being 0.2m thick, whilst the middle was 0.4m and the lower 0.95m thick. Mining of the lowest/thickest leaf of the Lower Pinchin Seam is known to have been extensive in the Pantteg area.

The sandstone layer that forms the cliffs at the back of the Pantteg landslip is known as the Llynfi Rock; this is the unit that was quarried for building stone at Cwar Pen-y-graig-arw.

Within the area of the Godre'r Graig landslip, the geology passes up through the entire thickness of the Llynfi Member, which predominantly consists of sandstones with sub-ordinate siltstones and mudstones. The summit of Mynydd Allt-y-graig, above the backscarp of the landslip area, is composed of the overlying sandstone of the Rhondda Member.

4.2 Structural Geology

A north-south trending fault is identified on the BGS published map, its alignment being roughly analogous to the western extent of the Godre'r Graig landslip. This could be one controlling feature of the location of the backscarp, although landslip material has been identified to the west of the fault outcrop.

4.3 Superficial Deposits

Glacio Fluvial deposits have been identified on the valley floor, along the line of Swansea Canal / A4067, whilst the majority of the level valley floor is covered by Alluvial deposits.

There also appear to be superficial deposits mantling the hillside above the backscarp of the landslips, generally consisting of weathered Coal Measures.

4.4 Landslip Deposits

In the Pantteg landslip, the 'solid geology' has a mantling of landslipped material.

The 1989 report interpreted there to be two main 'landslide subsystems', divided into upper and lower, as indicated on Dwg No KC/LVB/R1/3; this drawing is included in Appendix D.

The 'Upper' system was a result of rotational and toppling failures in the Llynfi rock sandstone cliff at the top of the Pantteg landslip. The terrace area below the cliff is subject to instability, but also features large boulders that must have come from the cliffs. The interpretation was that the failure was founded along the line of the Lower Pinchin Coal Seam, and involved rotational failures.

The 'Lower' system extended downslope from the upper, suggesting the scarp slope of the rear of the failure was to the rear of the minor terrace that follows the apparent line of the outcrop of the claystone band that contained the Upper Cwmgorse Marine Band. The failure would be a larger rotational slide.

Inspection in 2013 and the pattern of the December 2012 failure suggest that the two 'systems' overlap; material fallen from the cliffs at the rear of the Pantteg fault zone surcharge the unstable material below, driving a top down failure mechanism. Consequently, landslipped material can be found mantling the entire slope, except perhaps where a recent failure has removed this material.

4.5 Groundwater

The inspected areas of the landslips were generally dry underfoot, the only watercourses seeming to be related to outflows from old mining operations which are effectively acting as drains for any groundwater.

However, it should be noted that the inspection was undertaken in early summer, after a prolonged dry spell; an inspection in the middle of winter is likely to reveal seasonal surface water features not apparent during the June inspection.

The Hydrogeology section of the 1989 report [ref.2] indicates that infiltrating rainfall supplies water into the Llynfi Sandstone, which then penetrates down to the underlying Lower Pinchin coal seam. Historical mining within the coal seam probably allows concentration of water, which will preferentially drain along the lines of the adits.

Piezometers installed during the 1989 ground investigations suggest that groundwater also concentrates along the Thin Coal strata at the base of the claystone band that forms the ledge at the top of the 2013 landslip remediation. Monitoring indicated that water levels were related to rainfall events.

This is confirmed by the seepage line revealed following the regrading works in early 2013, as highlighted by dark staining and vegetation on Plates, A-5, A-11 and B-5.

The 1989 report concluded that there was little evidence that the outflow from the adits in the Lower Pinchin seam were causing significant inflow of water into the landslip. However, the combined flows from the (leaking) mine drainage system, groundwater seepage line and historical coal mining were identified as major contributory factors in the Pantteg failure.

A network of surface drainage, in the form of large diameter pipe systems was installed during the 1950s and 60s; the majority of these drain water from the adits draining the Lower Pinchin seam. The 1998 Hazard and Risk Map indicates three separate systems, as follows:

4.5.1 Cilbrwyn system

At the south-western extremity of the site, a stream runs across the hillside above the backscarp of the Godre'r Graig slip, bringing water from the vicinity of the old coal mines above Patagonia Farm in a manmade watercourse. The stream bed is cut into the superficial deposits, running in a deeply incised channel that reaches an estimated depth in excess of 2m where it crosses the footpath above the backscarp of the slip. The stream then descends a waterfall where it crosses over the backscarp of the slip, estimated to be 3-4m high.

The pipe system starts at the foot of the waterfall, where an inlet headwall was created to collect the water from the stream. Twin pipes then follow the approximate line of the stream to a second inlet on the north-west side of the Graig Road, opposite the entrance to Cilbrwyn. The watercourse passes under the road to emerge and continue down to the valley floor.

This upper inlet is no longer maintained. It is understood from the client's engineer that maintenance of this system used to consist of clearing the upper inlet using a mechanical excavator. However, as the inlet would block immediately during the first heavy rainfall following clearance, maintenance was required after every heavy rainfall event.

As a result of this experience the drainage engineer assessed that there was no benefit in attempting to maintain the inlet, resulting in the water flow reverting to the original open channel. Access to the upper inlet with a mechanical excavator is no longer possible due to vegetation growth.

With the water reverted to flow along the original stream route, this could allow water to saturate the lower part of the landslip area at the western extremity of the Godre'r Graig landslip. This could potentially trigger ground movements in the immediate vicinity of the stream, due to saturation of the superficial deposits. If there were ground movements in this area, there are no occupied properties directly downslope of the stream, however such an event may impact on the Graig Road where it gives access to Cilbrwyn.

4.5.2 Church Road System

A simple system collecting the outfall from two adits on the hillside above the junction of Church Road and Graig Road. The water is directed under Graig Road to emerge as a stream that flows along the southern edge of the Cemetery. The adits appear to have accessed the Lower Pinchin seam.

It was not possible to inspect any part of this system, due to the steepness of the slope and the density of the vegetation.

However it was noted that there was a flow of water over the retaining wall on the uphill side of the Graig Road at this location, which suggests that either the drainage system is leaking into the surrounding ground, or that the ground at this location is already saturated (from other sources) and the drainage system is not dealing with this.

Consequently it is recommended that this area is revisited during the winter in order to assess the drainage system and identify whether the water at the Graig Road is from the drainage system, or another source. Some site clearance may be required to achieve this.

4.5.3 Penygraig System

A network of pipelines collect and intercept water from the sandstone quarry, two old adits to the west of the quarry entrance, and the cliff face to the rear of the former site of Penygraig House. The main carrier pipe then descends the steep slope to the west of the Penygraig House site, to outfall into the highway drainage system on Mount Hill, opposite No.56 Pantteg.

The adit drains are all related to the elevations of the Lower Pinchin coal seam.

The alignment of the pipeline within the sandstone quarry could be traced by the presence of inspection chamber covers. However it was not possible to inspect the alignment east of the path due to the density of the ground cover. It is recommended that this area is revisited during the winter in order to assess the drainage system. Some site clearance may be required to achieve this.

The section where the pipe flows down the slope of the Pantteg Landslip was severed and partially destroyed during the December 2012 failure. This section has been repaired and reinstated as part of the 2012 site works, which also resulted in the demolition of Penygraig house.

5 Hazard & Risk Mapping

5.1 Previous Assessments

The original Hazard and Risk mapping exercise was carried out by Sir William Halcrow and Partners in 1987 [ref.1]. This covered the areas of both the Pantteg and Godre'r Graig landslips to assess the landslide hazards and the risks to properties and infrastructure in the settlement areas of Pantyffynnon, Pantteg and Craig y Merched.

The follow up report in 1989 [ref.2] detailed the ground investigation works that had been undertaken, allowing the geological strata to be assessed and ground models to be produced. The report concluded that the area was affected by two large landslide complexes, which had been initiated in ancient times. These had effectively self stabilised, but movement restarted in the 20th Century in the form of small scale landslides and falls, with 20 events being recorded between 1946 and 1987.

The reports identified that historically, all of the instability events could be related to periods of heavy rainfall, but it was thought that human activity had also contributed to the renewal of ground movements. These activities were identified as:

- Excavation of quarries causing removal of support from the landslide deposits;
- Disruption of the surface drainage systems;
- Modification of ground water flows as a result of mine workings;
- Discharge of a major stream into the ground water system.

The stability hazard and risk assessment was revisited in 1998 by NPT CBC, with the production of an updated Hazard and Risk map [ref.3].

5.2 Previous Methodology

The previous landslide hazard assessments were carried out based upon the then currently identifiable activity of the various landslide processes. The studies divided the area into three landslide hazard zones, as follows:

Table 5-A Landslide Hazard Zones as identified in previous reports

Zone	*Description*
High Hazard	Area with active slope processes with relatively large displacements. High probability of continued movement within the lifetime of the property at risk.
Medium Hazard	Area with recent slope movement but largely inactive at present. Moderate probability of failure in response to abnormally large rainfall events within the lifetime of the property at risk.
Low Hazard	Area with no sign of recent activity and low probability of failure within the lifetime of the property at risk

It is recognised that the terms 'High', Medium' and 'Low' Hazard are qualitative terms only, related to the stability conditions within the landslip sites covered by these reports. It should also be noted that extreme frequency-magnitude events (or external artificial influences) may cause failures in areas currently classified as low hazard.

Based upon the Hazard Zones designated in Table 6-A, the various highways and structures within the study area were divided into a number of risk categories. The original 1987 report had four divisions, although one of these was effectively 'uncertain – to be classified'; properties subjected to uncertainty were reclassified in 1989, and consequently only three designations have been used, as described in Table 6-B.

Table 5-B Landslide Risk Categorisation as identified in previous reports

Category	*Description*
1	Property or road within a high or medium hazard zone or within the likely trajectory of a landslide from such an area. Total loss of property likely and personal injuries are possible.
2	Property or road within a high or medium hazard zone or within the likely trajectory of a landslide from such an area. Due to reasons of location and/or topography the property is unlikely to suffer total loss and personal injuries are less likely.
3	Property or road within a low hazard area which is largely outside the direct effects of failures higher on the hillside in the present conditions.

The 1989 map and the subsequent 1997 version [ref.3] only classified the risk to highways and properties, making no direct reference to statutory undertakers plant, land quality or other receptors.

In addition, the maps also identified buildings as uninhabited – and consequently did not give them a risk rating. It is noted that in the time since the last assessment, some of these empty properties have been re-occupied.

5.3 2013 Assessment and Revision

The existing method of classifying the Hazard and Risk has been continued. The adoption of the system has been based upon the visual and desk study evidence as described in Table 5-C:

Table 5-C Landslide Hazard Zones

Hazard Zone	Description	Reasons for classification
High	Area with active slope processes with relatively large displacements. High probability of continued movement within the lifetime of the property at risk.	Presence of tension cracks and ground movements, evidence from distress (telegraph poles, fences, etc). Also geological horizons with a recent history of instability.
Medium	Area with recent slope movement but largely inactive at present. Moderate probability of failure within the lifetime of the property at risk.	Areas that have exhibited instability within recent history, which may not have fully stabilised.
Low	Area with no sign of recent activity and low probability of failure within the lifetime of the property at risk	Area within the identified boundary of the landslips, with no visual evidence of recent movement.

Potential reasons for continued movement or failure are taken as:

- Extreme rainfall events
- Increase in loading of the slope
- Change in slope geometry, due to excavation.
- Failure of existing drainage systems, introducing water into previously dryer areas

The classification is based upon visual evidence seen on site visits during 2013 by Jacobs geotechnical engineers. Some evidence of instability may not have been seen, due to accessibility difficulties as a result of vegetation growth or unsafe topography. In addition the main inspection was carried out following a prolonged dry period, so evidence of groundwater seepage may have been reduced.

A minor amendment has been to classify currently unoccupied properties. The base map indicates the historical presence of buildings that may, or may not be habitable; in some cases the current structure is just the walls, but in others the house remains intact. Experience has demonstrated that previously empty properties in the area can become re-occupied between assessments, resulting in occupied houses with no classification.

This assessment is both qualitative and judgemental, and should be kept under regular review.

6 Stability Assessment

6.1 Engineering Assessment

The re-assessment of the stability hazards and risk is based upon the previous investigations, and the walk over survey carried out in June 2013.

A revised Hazard and Risk Map is presented in Appendix D.

6.1.1 Interpretation

The ongoing instability at Pantteg and Godre'r Graig is probably the result of the following factors:

- Structural geology results in a slight dip towards the valley.
- Lithologically there are alternating competent and incompetent strata.
- Naturally steep slopes, close to the angle of repose of the superficial materials.
- Rainfall, in terms of surface water runoff and recharging groundwater.
- Historical mining has created groundwater pathways to lubricate the incompetent strata.
- Collapse of rock from the Llynfi sandstone cliffs at the top of the slope surcharge the top of the slope.
- Presence of loose / soft material from previous landslides.
- Leakage from mine drainage systems.

In addition

- Historical house construction at the foot of the slope could have resulted in undermining marginally stable slopes.
- Trees on the slope may cause instability.

6.1.2 Pantteg Landslip

In general, the area of failure that creates the highest risk is above the line of the old valley road (Graig Road / Pantteg / Cyfyng Road), where the topography is significantly steeper than below. This profile can clearly be seen at Pantteg following the 2013 stabilisation works, which involved the removal of the loose and failed material, resulting in current profile.

Recent failures in 2012 and 2013 confirm the correlation between ongoing instability and periods of extreme and/or intense rainfall. They are also related to the position of the Thin Coal seam at the foot of the 'rock ledge', which it is speculated may be one of the levels at which groundwater is concentrated due to the presence of the historical adit systems.

The 1987 failure to the rear of No.29 Pantteg also appears to have started at this stratigraphical level, as did the 1986 landslide at Craig-y-Merched. Consequently, all of the recent failures appear to be occurring along the line of the outcrop of the claystone containing the Cwmgorse Marine Band, where it is believed that any groundwater is being concentrated along the horizon of the Thin Coal Seam. This suggests that there is a high risk that failures will continue to occur at this horizon, both to the north-east and south-west of the recent failures. The area of the 2012 failure, which has undergone remedial regrading works, has been classified as a Medium Hazard area, as it will still be subject to the effects of failures above the remediated slope and experience some minor degradation of its own.

The hillside above Pantteg is currently showing signs of distress upslope from the area of the December 2012 failure and 2013 remediation works, and it is anticipated that instability will continue. This distress is in the form of tension cracks, and other evidence of ground surface extension, such as stretched fencelines and tilting trees. The superficial materials above the regraded area are moving downslope, and are likely to result in slope failures above the recent remedial works, and extending either way along the slope from the 2012 failure.

The 2013 remediation left a ‘rock band’ in place to act as a catch area to slow the encroachment of any material that slips down from above. However, it is noted that the ‘rock band’ itself is failing (locally) and so this function may be compromised.

Any landslips that occur above the 2013 remedial works will be slowed by the presence of the rock band and eventually the ditch and bund at the foot of the slope; opposite the chapel at Pantteg there is now a reasonable ‘run out’ and ‘catch’ area, which should ameliorate the effects of any future landslips at this location. But it should be noted that works in this area comprised rapidly implemented risk reduction measures, consequently the area was not formally designed, and consequently there is still a residual risk that future failures may encroach onto the highway.

Beyond the extent of the 2013 remedial works the area of designated High Hazard has been extended to encompass the area downslope of the Thin Coal outcrop, including the bulging hillside above the junction of Church Road and Graig Road / Pantteg.

The ground model of the site indicates that the area below (south-east) of the old valley road (Pantteg / Cyfyng Road), the most densely populated part of the site, comprises houses constructed on historical landslip material (colluvium). As far as Jacobs are aware, there have been no reports of distress to buildings in this area, and the area was not inspected in any detail during the site inspection. There is a risk of future movements in this area, as the stability may be marginal, and only a minor change in influencing conditions may be required to initiate movement.

Because of the nature of the underlying ground and the density of the population, a monitoring system should be installed.

6.1.3 Godre'r Graig Landslip

Movement of the Godre'r Graig Landslip has resulted in the abandonment and destruction of the village of Pantyffynon above (north-west of) the Graig Road, with only a few houses remaining to the south-east of the road. The road itself has been blocked off as a through route although the alignment is still intact.

There do not appear to be any revisions required to the previous assessment.

6.2 Specific Concerns

The Client has requested that the following issues are specifically addressed in this review:

6.2.1 Maintenance of the Cilbrwyn drainage system

The client asked "*The overland drainage system above the Cilbrwyn Club - the system which we cannot maintain - is it of benefit?*"

Critical maintenance appears to be the clearance of the inlet headwall at the top of the Cilbrwyn drainage system, which it is understood becomes blocked after every major rainfall event. It is understood that this has not been carried out for some time, and consequently access to the inlet headwall is now difficult due vegetation growth.

With the inlet blocked, the stream has re-occupied its original channel, naturally achieving an open drainage system. It is understood that erosion and deposition of stone in the channel has naturally lined the lower ditch, forming a cascade.

Given the erosion of the channel upstream, even if the inlet headwall is regularly kept clear, material will find its way into the overland drainage pipes and eventually cause a blockage, which could be impossible to clear.

The challenges of maintaining the drainage pipework suggests that a better option in this area would be an 'open' drainage system, such as 'V' ditches, which are generally easier to inspect and maintain, as they are generally self cleaning. As this has naturally occurred already, it is recommended that a formal inspection regime is instigated. Periodic maintenance, such as clearing oversize debris to maintain flow, may be needed.

6.2.2 The bulge in the mountain opposite the rear of Nos 1 to 6 Church Road

It was noted that the ground close to the road appeared to be saturated, and water was flowing down the face of the retaining wall on the uphill side of the road. However, it was not possible to inspect the ground above this area for signs of extension or failure due to the density of the vegetation.

Given the pattern of the recent failures to the north-east, it is possible that the water is coming from within the claystone above the Thin Coal seam, or a failure of the mine drainage system. Consequently this section of the site has been designated as high risk following the recent failure opposite Pantteg Chapel where similar causes were identified.

A failure here could block the junction, and consequently totally block the access to the properties on Owen's Lane.

Due to the density of the vegetation at this location it is recommended that a further inspection of this area is undertaken during the winter months, when access should be possible, and groundwater flows are likely to be more traceable. This may require vegetation clearance works. A full response can then be provided following that inspection.

6.2.3 Presence of trees on the unstable slopes

Trees can be considered both an advantage and a disadvantage:

- Tree root systems can stabilise near surface soils and prevent erosion.
- However, trees also add weight to the ground – potentially adversely loading the ground. They are also subjected to wind loading, especially if at the edge of a freshly cleared area, and as the trees have not grown with this load, are more likely to be toppled by extreme weather – which will destabilise the slope and be a direct hazard in themselves.
- Mature trees can also destabilise rock through root wedging.
- Dense tree growth makes access to and inspection of the ground difficult.

Given the hazard caused by falling trees in the 2012 landslip at Pantteg, it is recommended that trees that are at risk of falling onto the highway should be cleared.

This will prevent highway blockage caused by minor localised failures, and potentially reduce the risk of highway blockage in any future landslips. Consideration should then be given to replanting with low growing vegetation to assist in preventing erosion.

6.2.4 Drainage of exposed slope opposite chapel

The client asked "*Drainage of exposed slope opposite chapel, any advantage or potential harm*"?

Installation of conventional gravel filled ditches may result in the gravel becoming clogged, as maintenance will be almost impossible. Open 'V' ditches down the slope are the best option as they should, to some extent, be self cleaning and obvious blockages can be readily observed.

However, it is noted that the installation of any drainage on the slope is likely to be very difficult to achieve safely due to the slope geometry.

There are two potential failure mechanisms that will affect this area. Failure of the superficial deposits on the slope, and failure of the material above the regraded area.

The advantage of installing drainage would be to reduce the risk of surface saturation and failure of the regraded slope. However, following the regrading works

in this area, there is only a limited amount of superficial material left in-situ that can be destabilised by saturation from groundwater, and any failure of this type should be caught within the run-out area.

Consequently, the main present risk of instability at this location is driven by the movement of the ground above the area of remediation, which will load the ledge at the top of the slope. Installation of drainage of the slope will not reduce this risk.

Consequently, there is no significant advantage in installing drainage on the exposed slope.

6.2.5 Improvement of rock barrier opposite chapel

The main benefit of the 2013 regrading works was to remove the failed material from the slope and reducing the potential for future failures of the material. In achieving this it allowed the creation of a drainage ditch and berm at the foot of the slope, and a longer run-out area opposite Pantteg Chapel. These features should reduce the risk of future instability further upslope of blocking the highway, although it is noted that this is not a formally designed system, and so this cannot be quantified.

In order to maximise the effectiveness of the run-out area it is recommended that the 'rock barrier' should be moved closer to the ditch to (a) provide greater volume of catchment and (b) give any failed material more distance to slow its descent before it encounters the barrier, thus making the barrier more effective.

Raising the height of the barrier will also improve its effectiveness.

In the event that landslip material passes the rock barrier it will still need to traverse the ditch and berm prior to reaching the highway.

6.2.6 Benefit of additional drainage on the mountain?

The client asked "Any advantage in installing additional drainage on the mountain, bear in mind practicality of installation and maintenance and cost"

The existing drainage systems are all collecting water from the vicinity of the Lower Pinchin coal seam, at the underside of the Llynfi Sandstone. However it seems that recent failures, ie over the last 25 years, all appear to be related to failures starting within the vicinity of the outcrop of the Thin Coal, which is perceived as another groundwater bearing horizon.

In addition, there have been reports of the mine drainage systems leaking that could have contributed to past failures.

The existing system intercepts water emitting from adits, but there are no logical collection points lower down the slope, so a major investigation of the groundwater regime would be required to design a suitable system. Even then, there is no guarantee that this will stabilise the local area of the landslip.

The preferred option would be to target specific drainage to reduce the hazard and so reduce the risk to specific receptors.

Installation of drainage would be physically challenging, and unless they are self cleaning open ditches, then maintenance can become difficult, as experienced on the Cilbrwyn system.

A more practical way of dealing with the groundwater problem may be to regrade the lower slopes – as has been carried out opposite Pantteg Chapel – in order to reduce the volume of superficial material that is at risk of saturation from the groundwater. With a clearer slope, targeted drainage could then be installed.

7 Summary and Recommendations

7.1 Summary of Review

Ground conditions and instability at the site are complex and operate on a range of scales. Rates of movement vary across the site and movement can be triggered by a variety of influences, the intensity of which also varies across the site.

The risk and hazard map of the area has been updated, the changes to the previous (1999 [ref.3]) map being listed below:

- The primary changes are to the extent of the high hazard area. Recent failures appear to be generated in relationship to the position of the Thin Coal outcrop above Pantteg and consequently, the area of High Hazard has been extended to include this outcrop. The risk to properties and infrastructure downslope of this has been reviewed and amended.
- Evidence of movement on Graig-y-Merched indicates the upgrading to the High Hazard area should extend this far to the north-east.
- The bulging of the ground opposite the Church Road junction, combined with the line of the Thin Coal outcrop indicates that High Hazard area should extend to the south-west to Graig Road.
- The area of the 2012 failure and 2013 regrading works has been downgraded to Medium Hazard, but it is noted as being directly downslope of the High Hazard area in the slope above.
- Properties that were previously designated as 'unoccupied' have been given a risk classification, following experience of unoccupied propertied coming back into use.
- The area of Pantteg downslope of the old valley road (Pantteg / Cyfyng Road) was not fully inspected, but there are no reports of distress to this area. In the absence of contrary information, the hazard rating of this area has not been changed. However, stability in this area may be marginal, so further inspection and monitoring is recommended.

The Hazard and Risk map has been reviewed and updated, and is presented in Appendix E

The assessments of stability hazard and associated risk included within this report are qualitative, based upon site observation in conjunction with interrogation of the available historic investigation.

7.2 Recommendations

7.2.1 Future Monitoring

A further wide ranging inspection of the entire site should be carried out during the winter. During this time of year the vegetation has died back, which will allow easier access and visibility of parts of the slope it was not possible to traverse or see in the thick vegetation of the summer growth. This should also allow a greater appreciation of the existing slope drainage systems and potentially allow the identification of areas for the installation of additional targeted drainage. This should aim to target areas that were not inspected during the June inspection, and may require some vegetation clearance.

Ongoing inspections of the site should be carried out regularly to inspect for warning signs of further ground movements. The current inspections are essentially 'qualitative' based upon visual inspections. It is recommended that a 'quantitative' assessment system is set up, including the installation of a monitoring system so that rates of movement can be recorded and assessed. Any system could be targeted to cover the high risk areas.

Monitoring systems could consist of survey monuments upon the slopes so that surface movements can be tracked. Alternatively, consideration could be given to regular LIDAR surveys of the hillside, to allow detection of ground movements. Consideration should be given to 'in ground' instrumentation in the populated areas downslope of the road.

The assessment should be reviewed regularly in light of developing conditions at the site and at least annually to observe the effects of seasonal rainfall and associated groundwater conditions.

7.2.2 Risk Reduction Measures

Previous reports were of the conclusion that the overall landslip system could not be economically stabilised, and Jacobs concur with this opinion.

The site comprises a steep natural hillside, overall stability is marginal and it is not likely to be possible to achieve design factors of safety that provide reasonable surety against failure for any relatively localised scheme of works.

However, it is considered that targeted schemes could be undertaken as risk reduction measures, to reduce the hazard threatening vulnerable infrastructure and housing, such as maintaining the use of Graig Road and Pantteg (road) to access local properties, and the south end of Ystalyfera.

The following risk reduction measures could be considered:

- Move the rock barrier opposite the Chapel to be closer to the highway. Increase its height if possible.
- Clearing the trees above the highway in the High Hazard area for a distance back from the highway equivalent to the height of the trees, so that if any instability occurs, it is less likely to be exacerbated by the trees on the slope.

- Regrade the slope in the same pattern as carried out opposite Pantteg Chapel in 2013, especially on the slope opposite the Church Road junction. This would remove the material that is at risk of failure, and reduce the hazard of the area, and thus the risk to the road. Design of these works would require a site investigation to delimit the slope.

In addition, it is recommended that the client consider the use of the planning regime to limit the potential for any developments in the area that could have an adverse affect on the stability of the slope, including the residential area to the south-east off the old valley road (Pantteg / Cyfyng Road).

8 Risk Register

Risk Element	Residual Risk	Residual Risk Management
The entire area of the landslip(s) was not inspected due to access restrictions.	It is possible that some evidence of instability was not seen	Carry out further site inspections during the winter when access will be easier due to vegetation die back.
Groundwater seepage inspection was restricted due to access restrictions, and flows reduced due to dry weather.	Reduced rate of groundwater emergence during drier summer months, so possible seasonal flows could be missed.	Carry out further site inspections during the winter when precipitation is higher and the resultant groundwater flows will be more noticeable.
Area downhill of the old road (Pantteg and Cyfyng Road) was not inspected in any detail.	The most densely populated area is constructed on old slipped materials, and there is possible risk of instability.	Area should be inspected for evidence of distress to buildings. In ground monitoring (such as inclinometers) could be installed.
The condition of the Mine Drainage Pipes was difficult to assess due to access restrictions.	It is possible that some evidence of distress to the pipework or drainage systems was not seen. This could saturate the ground leading to further failures.	Carry out formal inspection of the drainage systems during winter when access is easier (vegetation dieback) and flows are anticipated to be increased.
Tension cracks on terrace above Pantteg.	Current monitoring regime may not identify date / time / extent of any future failure.	Regular visual monitoring. Enhancement of debris trap opposite Chapel if possible. Develop contingency plan should substantial movement occur.
Trees in areas on instability.	If trees included within future landslips the impact of the slip can be exacerbated.	Reduce the volume of trees on the slope in high risk areas.
Blockage of Mine Drainage system	Saturation of underlying materials causing instability.	Periodic inspection and maintenance of drainage systems.
Reactivation of large scale failure systems	Stability of large scale failure systems (upper and lower) is likely to be marginal with Factors of Safety below acceptable design values. Environmental change may trigger further movements.	Develop and implement a monitoring strategy for the site, targeting high risk areas. Undertake regular review on monitoring data and update hazard/risk plans as necessary.

9 References

1. Sir William Halcrow and Partners, *Godre'r Graig & Pantteg Landslides, Report on Hazard Mapping*, report for the Lliw Valley Borough Council, July 1987.

2. Sir William Halcrow and Partners, *Pantteg Landslide, Report on Ground Investigation*, report for Lliw Valley Borough Council, December 1989.

3. Neath Port Talbot County Borough Council, *Pantteg and Godre'r Graig Landslide Area, Report on Assessment of Landslide Hazard*, February 1998.

4. British Geological Survey, Geology of Britain; http://www.bgs.ac.uk/data/mapViewers/home.html

5. British Geological Survey, OpenGeoscience borehole logs, http://www.bgs.ac.uk/data/boreholescans/home.html

6. Jacobs, *Pant Teg Landslide, Ystalyfera: Site Inspection 7th January 2013*, letter to NPT CBC, 10 January 2013.

7. Jacobs, *Pant Teg Landslide, Ystalyfera: Site Inspection 25th February 2013*, letter to NPT CBC, 27 February 2013.

8. Jacobs, *Pant Teg Landslide, Ystalyfera: Validation of Remedial Works*, letter to NPT CBC, 9th April 2013.

Appendix A Site Photographs

Plate A-1: Pantteg, landslip December 2012, looking north-east towards the chapel.

Plate A-2: Pantteg, landslip December 2012, looking south-west at the chapel

Plate A-3: Pantteg, landslip December 2012, looking north-east towards the chapel hall

Plate A-4: Pantteg, landslip December 2012, looking south-west from the chapel hall

Plate A-5: Pantteg – overall view of 2013 regrading works

Plate A-6: Pantteg – regraded slope from the south-west.

Plate A-7: Pantteg – regraded slope from the north-east.

Plate A-8: View down to Pantteg chapel from fissures above 2012 failure

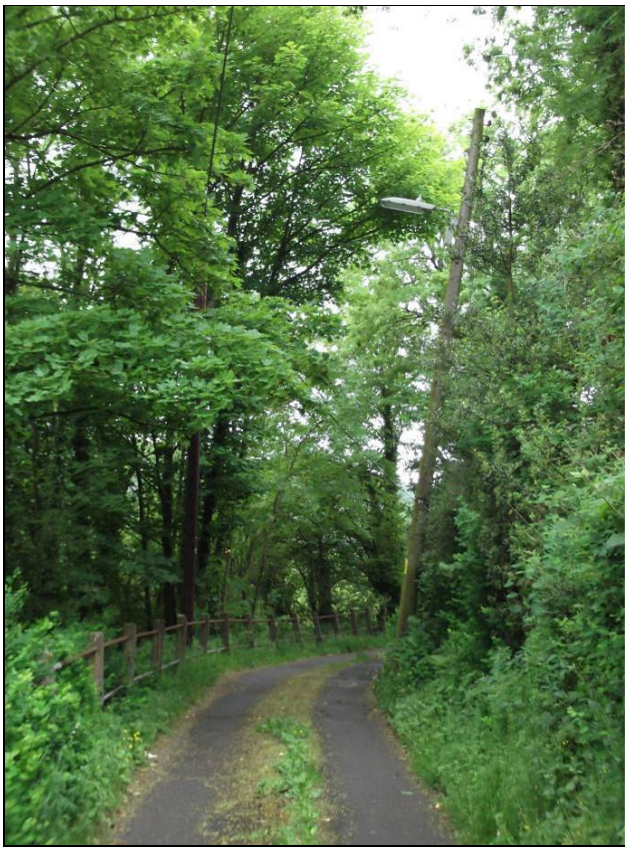
Plate A-9: Fissures in the slope above Pantteg Chapel

Plate A-10: Fissures in the slope above Pantteg Chapel

Plate A-11: Remediated area opposite the Chapel (11-06-13)

Plate A-12: The same area as above on 07-08-13, showing movement of the ledge.

Plate A-13: Graig-y-Merched, looking south-west



New telegraph pole on the left, approximately vertical.

On the right is the old telegraph pole, also supporting the streetlight. This is leaning at an angle. This lean is caused by the taughtness of the power cables, which have pulled the pole over into the radius of the curve, providing evidence of ground movement.

Plate A-14: Cyfyng Road retaining wall, looking south-west – no visual evidence of distress.

Appendix B Long Range Photographs

Plate B-1: Godre'r Graig Landslip (Western Section)

Plate B-2: Godre'r Graig Landslip (Central Section)

Plate B-3: Godre'r Graig Landslip (Eastern Section)

Plate B-4: Pantteg Landslip area

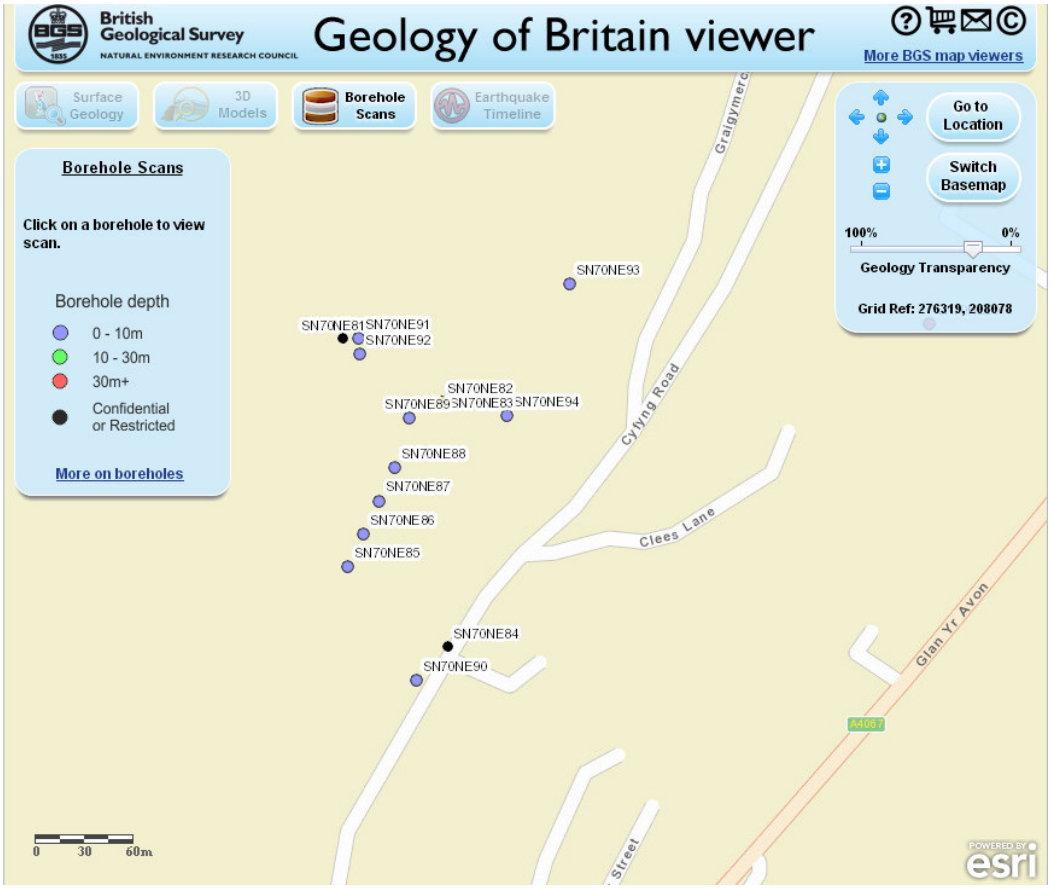
Plate B-5: Pantteg Landslip area, showing extent of 2013 regrading works.

Plate B-6: Pantteg Landslip area, showing extent of the fissuring on the hillside above the 2013 regrading.

Appendix C Ground Investigation Information

Trial Hole Location Plan, from BGS Website

http://mapapps.bgs.ac.uk/geologyofbritain/home.html

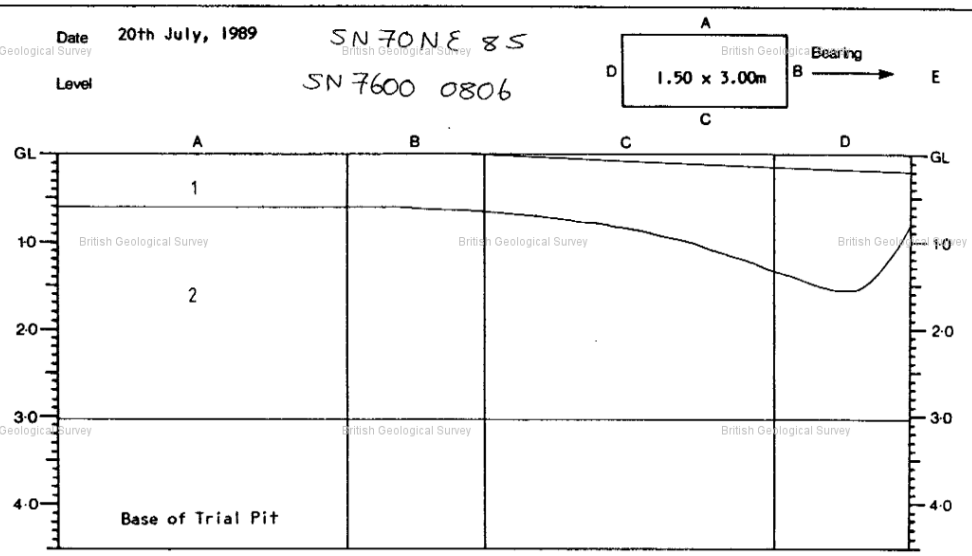


Trial Pits carried out as part of the 1989 investigation [ref.2], extracted from the BGS website, have been presented on the following pages.

SN70NE85

Date 20th July, 1989 SN70NE 85

Level SN 7600 0806



Samples Depth	Type	Strata No.	Description	Test Depth m.	Cu kN/m²	Remarks
G.L.– 1.50	B	1	Topsoil over loose mid grey to brown grey, angular to sub-angular slightly clayey, fine sandy fine to coarse GRAVEL COBBLES and some small boulder sized fragments of moderately weathered micaceous fine sandstone with some rootlets to 0.40m. (Colluvium)			
1.50– 3.00	B	2	Boulders of closely to very closely bedded slightly to moderately weathered, IRONSTONE SHALE, moderately weak to moderately strong. Close to medium spaced vertical joints, open, infilled. Becoming more massive below 1.50m (Face A) to 2.00m (Face B). General dip – 15 – 20° south. (spalled blocks, weathering in situ)			

Plant	POCLAIN 62	Water	Damp, below 0.60m. Very slight seepage from base of 1. in Face B.	Cu - Approximate value of un-drained shear strength from hand vane
Shored to	-	Stability	Severe spalling all faces.	

Trial Pit Record

exploration associates

Project

Llw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP01

EX 10

JACOBS

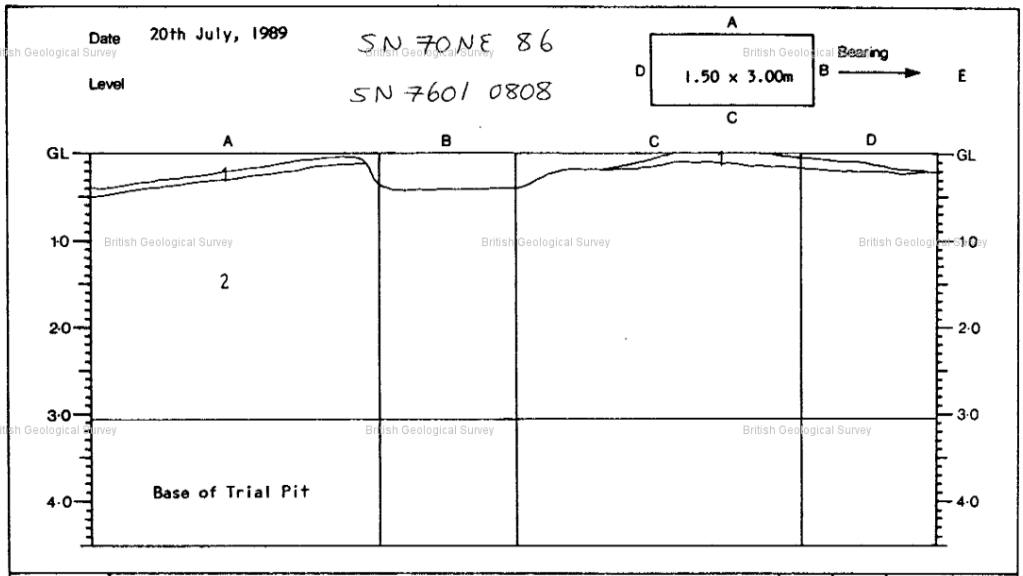
SN70NE86

Date 20th July, 1989

Level

SN 70 NE 86

SN 7601 0808



Samples Depth	Type	Strata No.	Description	Test Depth m.	Cu kN/m²	Remarks
0.10-3.00	B	1	TOPSOIL.			
		2	Dark grey to black, stained orange brown, moderately weathered, very thinly bedded, micaceous, carbonaceous, SHALE, moderately weak closely spaced, irregular vertical joints. Face A: Occasional closely spaced, vertical, pervasive joints, trend - N-S. Much orange brown, ferrous, staining on bedding and joint surfaces.			

Plant	POCLAIN 62	Water	Damp below 0.50m.	Cu - Approximate value of un-drained shear strength from hand vane
Shored to	-	Stability	Slight/moderately spalling from A,B,D.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

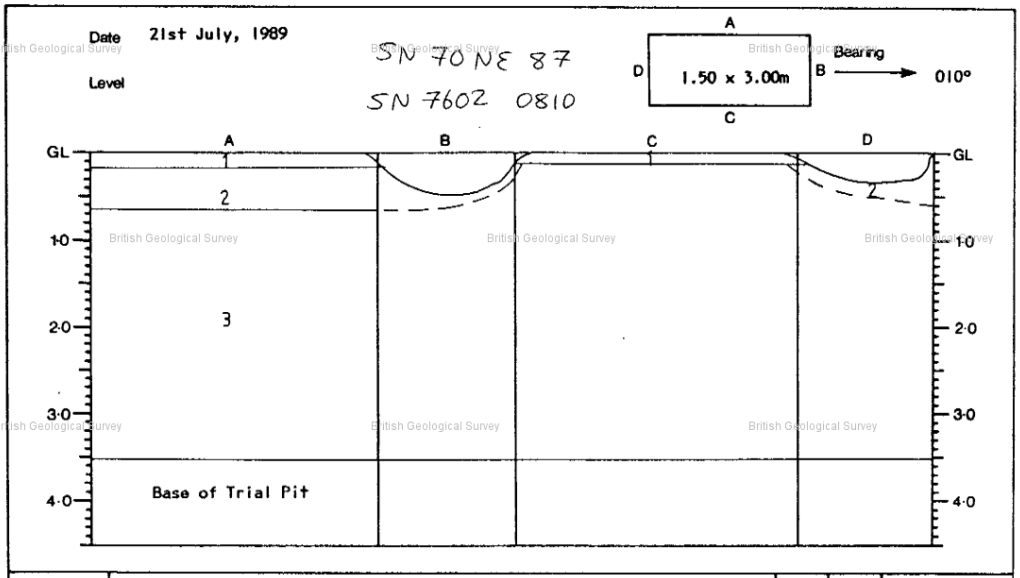
Contract H9169

Trial Pit TP02

EX 10

JACOBS

SN70NE87



Samples		Strata		Test Depth m.	Cu kN/m²	Remarks
Depth	Type	No.	Description			
		1	TOPSOIL.			
		2	Loose, angular imbricated fine to coarse GRAVEL of ironstone shale with some soft to firm silty clay and infilling. (Colluvium)			
		3	Loose to medium dense, highly weathered, angular, tabular, imbricated fine to coarse GRAVEL and COBBLES of ironstone shale with occasional boulders of moderately weathered, shaley fine sandstone. Some thin clay coating and infilling (possibly weathered in situ rock material).			

Plant	POCLAIN 62	Water	Damp below 0.60m.	Cu - Approximate value of un-drained shear strength from hand vane
Shored to	–	Stability	Severe spalling from A,B,C.	

Trial Pit Record

exploration associates

Project

Llw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP03

FX 10

JACOBS

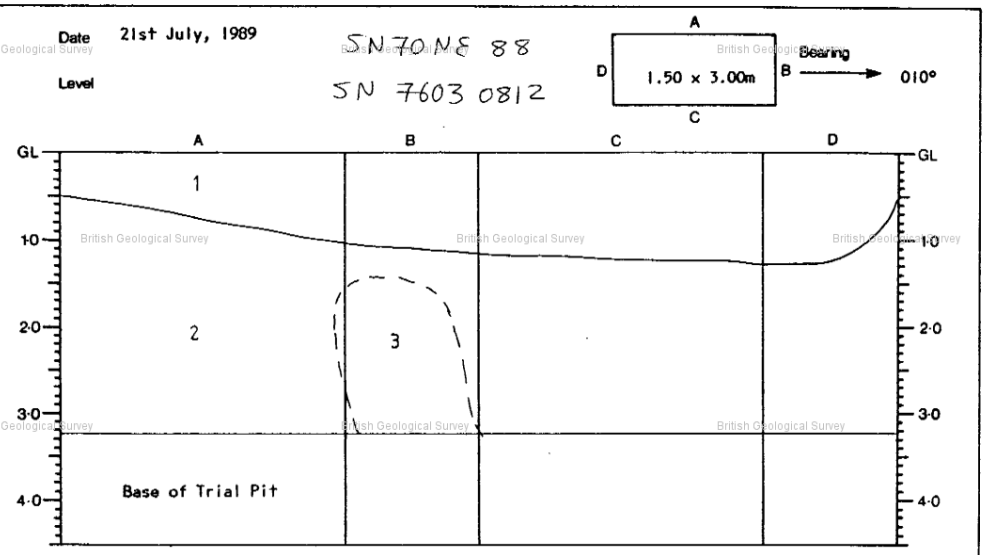
SN70NE88

Date 21st July, 1989

Level

SN70NE 88

SN 7603 0812



Samples Depth	Type	Strata No.	Description	Test Depth m.	Cu kN/m²	Remarks
		1	Topsoil over loose, randomly orientated, angular fine to coarse GRAVEL of ironstone shale with a little to some matrix of residual sandy clay.			
2.20-3.20	B	2	Mid grey, moderately to highly weathered, very thinly bedded to thickly laminated, extremely closely fractured IRONSTONE SHALE with much orange brown, iron-oxide staining on bedding and joint surfaces. Occasional medium spaced, sub-vertical, sub-planar joints with a little thin clay coating on surfaces (trend 118° (ESE)). Becoming medium to thickly bedded below 1.90m.			
		3	Medium dense, brown grey, angular fine to medium, occasionally coarse, clayey, GRAVEL of shale with some fine gravel sized coal fragments.			

Plant	POCLAIN 62	Water	Damp in 3. below 2.20m.	Cu - Approximate value of undrained shear strength from hand vane
Shored to	-	Stability	Severe caving in B,C,D.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP04

EX 10

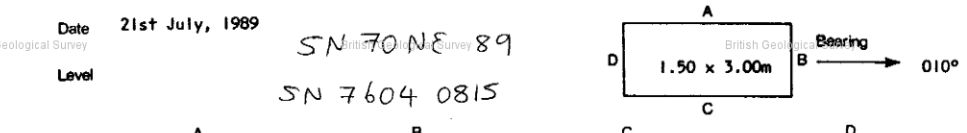
SN70NE89

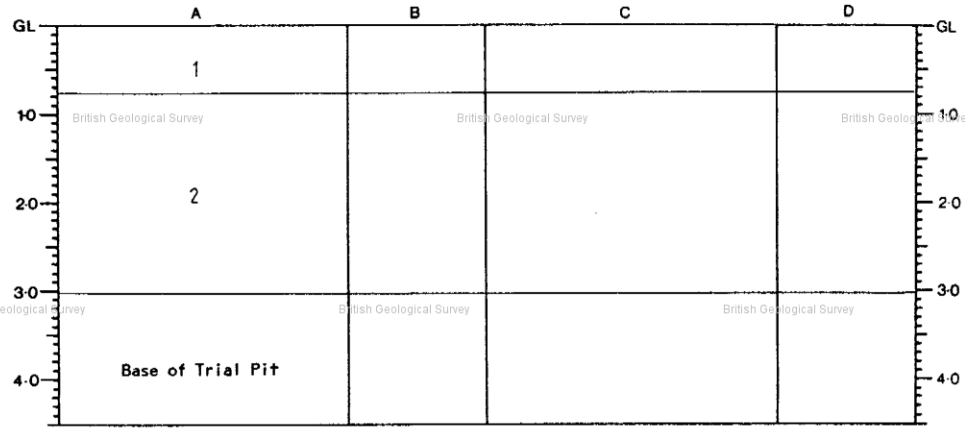
Date 21st July, 1989

Level

SN 70 NE 89

SN 7604 0815





Samples		Strata		Test Depth m.	Cu kN/m²	Remarks
Depth	Type	No.	Description			
		1	Topsoil over loose, randonly orientated, angular fine to coarse GRAVEL of sandstone with some rootlets to 0.50m. (Colluvium)			
		2	Loose, angular, tabular, fine to coarse GRAVEL and COBBLES with occasional boulders of fine to medium grained sandstone. Poorly developed imbricate frabric, strike = 030° (ESE). (Colluvium)			

Plant	POCLAIN 62	Water	Dry.	Cu-Approximate value of un-drained shear strength from hand vane
Shored to	-	Stability	Severe caving, all faces.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP05

EX 10

JACOBS

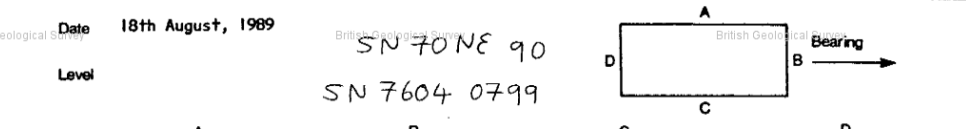
SN70NO90

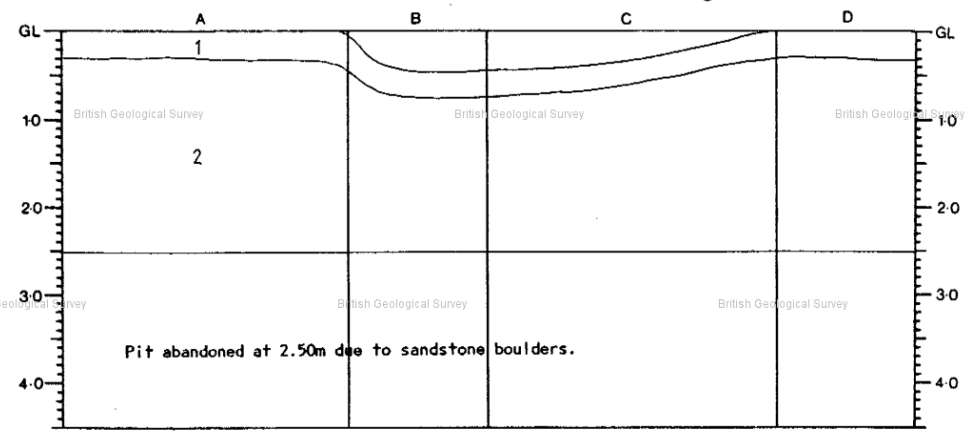
Date 18th August, 1989

Level

SN 70 NE 90

SN 7604 0799





Samples		Strata		Test Depth m.	Cu kN/m²	Remarks
Depth	Type	No.	Description			
1.50-2.50	B	1	Turf over topsoil, loose to medium dense, brown, silty slightly clayey fine sand with much sub-angular, fine to medium occasional coarse gravel of sandstone.			
		2	MADE GROUND: Firm to stiff, mid brown mottled yellow brown and black, silty slightly sandy clay with some to much, sub-angular to angular fine to coarse gravel and cobbles, with occasional blocks to 0.50m of sandstone/building stone and some brick and coal fragments, occasional pockets of firm/soft grey silty clay to 0.30m across. Bands of sandstone cobbles/boulders at 0.30m to 0.90m; 1.90m to 2.30m; 2.50m.			

Plant	POCLAIN 61	Water	Damp below 0.50m.	Cu-Approximate value of undrained shear strength from hand vane
Shored to	-	Stability	Slight caving in A & C at 1.50-2.00m.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP06

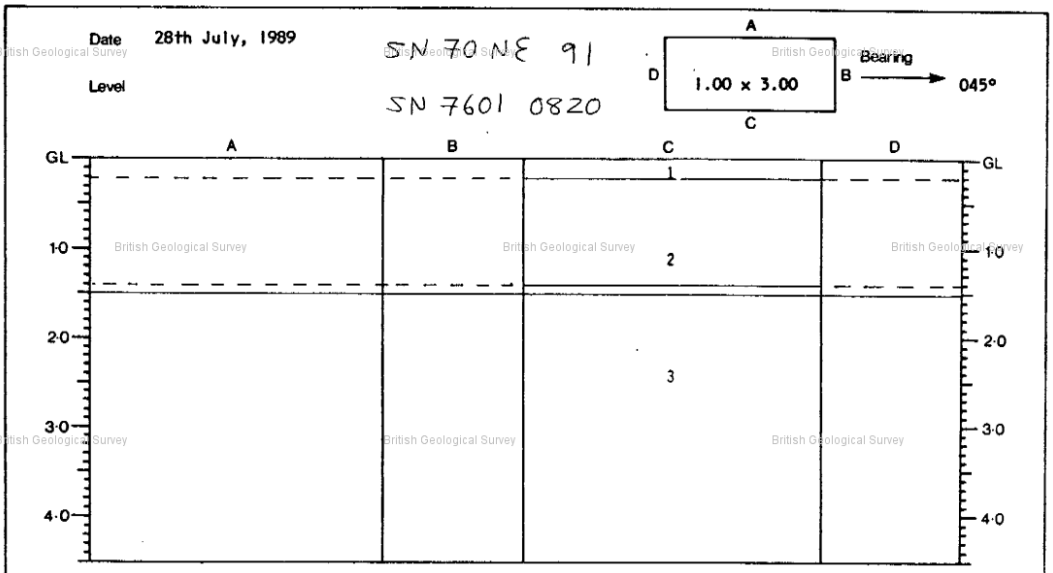
EX 10

JACOBS

SN70NE91

Date 28th July, 1989 SN 70 NE 91

Level SN 7601 0820



Samples Depth	Type	Strata No.	Description	Test Depth m.	Cu kN/m²	Remarks
1.45–1.50	B	1	Firm grey brown silty TOPSOIL.			Pit logged by Engineer's staff
		2	Firm/dense light brown very gravelly SILT and SAND with some cobbles of sandstone containing rounded dark grey iron-rich nodules.			
		3	Brown orange grey coarse grained IRONSTONE, very strong.			

Plant	POCLAIN 62	Water	Dry.	Cu-Approximate value of un-drained shear strength from hand vane
Shored to	–	Stability	Stable.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP07

EX 10

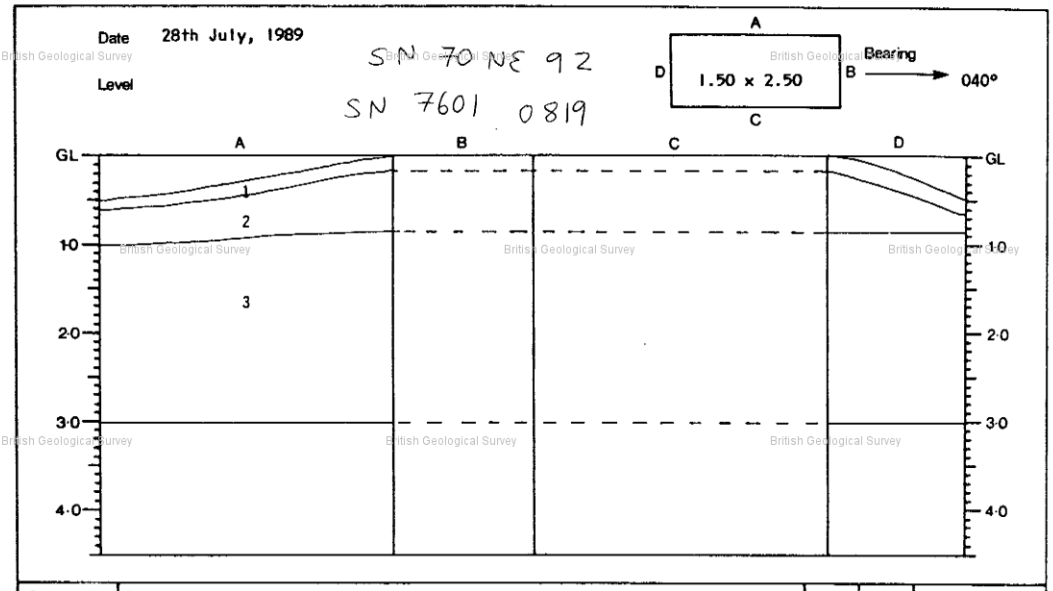
SN70NE92

Date 28th July, 1989

Level

SN 70 NE 92

SN 7601 0819



Samples Depth	Type	Strata No.	Description	Test Depth m.	Cu kN/m²	Remarks
NONE TAKEN		1	Loose mid brown, silty TOPSOIL with rootlets.			Pit logged by Engineer's staff
		2	Firm/dense light brown very gravelly SAND and SILT.			
		3	Grey brown, thinly laminated moderately to highly weathered SANDSTONE, moderately strong. Some bands of ironstone and siltstone interbedded with sandstone.			

Plant	POCLAIN 62	Water	Dry.	Cu - Approximate value of undrained shear strength from hand vane
Shored to	-	Stability	Stable.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP08

EX 10

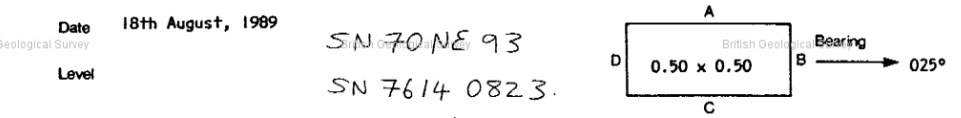
SN70NE93

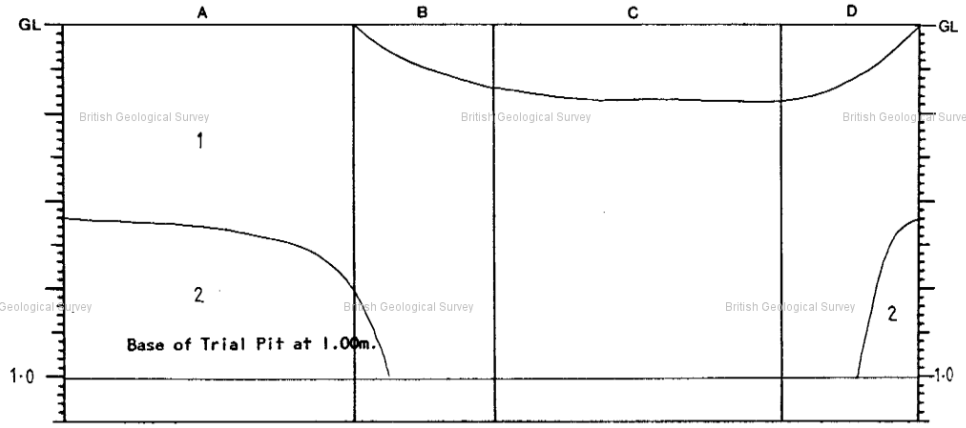
Date 18th August, 1989

Level

SN 70 NE 93

SN 7614 0823.





Samples Depth	Samples Type	Strata No.	Strata Description	Test Depth m.	Cu kN/m²	Remarks
G.L.–1.00	B	1	Loose, angular, occasionally sub-angular, tabular fine to coarse GRAVEL and some COBBLES of moderately to highly weathered, mid to dark grey, stained orange brown silty mudstone and silty fine sandstone, weak in matrix of firm mid brown to dark brown grey silty clay. (Colluvium)			
	B	2	Mid purple grey, heavily stained purple brown and mid brown, highly weathered, thinly laminated, silty MUDSTONE, very weak.			

Plant	Hand Dug	Water	Damp below 0.15m.	Cu - Approximate value of un-drained shear strength from hand vane
Shored to	-	Stability	Stable.	

Trial Pit Record

exploration associates

Project

Llw Valley Borough Council
Pantteg Landslide

Contract H9169

Trial Pit TP09

EX 10

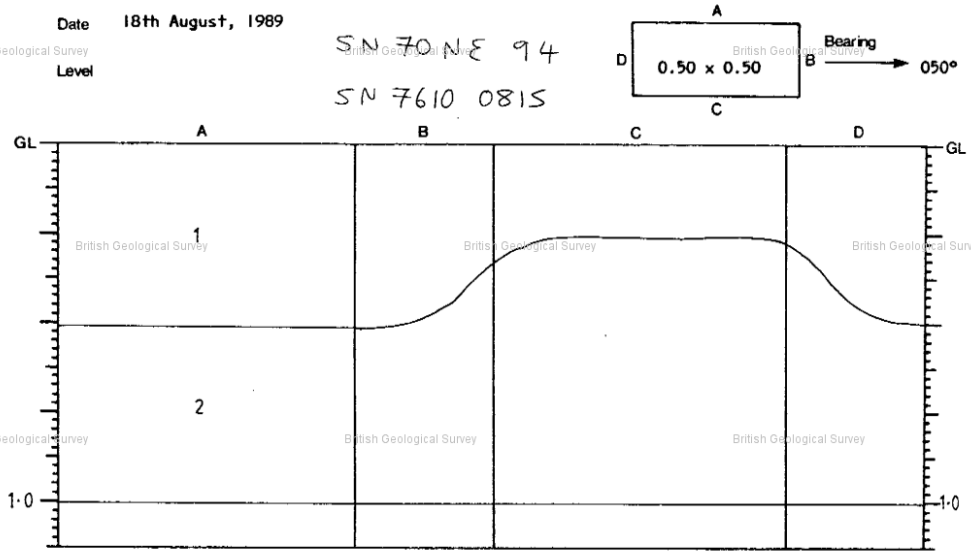
SN70NE94

Date 18th August, 1989

Level

SN 70 NE 94

SN 7610 0815



Samples		Strata		Test Depth m.	Cu kN/m²	Remarks
Depth	Type	No.	Description			
0.50-1.00	B	1	Turf over loose, angular, predominantly tabular, fine to coarse GRAVEL and COBBLES of moderately to highly weathered silty fine sandstone, moderately weak to moderately strong with a little matrix of firm, dark brown, silty clay. (Colluvium)			
		2	Loose to medium dense, angular, tabular, fine to coarse GRAVEL and occasional COBBLES, of silty fine sandstone, moderately weak to moderately strong with some matrix of firm, brown silty sandy clay. (Colluvium)			

Plant	Hand Dug	Water	Damp below 0.50m.	Cu-Approximate value of undrained shear strength from hand vane
Shored to	-	Stability	Slight caving in 2. at 0.30m.	

Trial Pit Record

exploration associates

Project

Lliw Valley Borough Council
Pantteg Landslide

Contract 119169

Trial Pit TP10

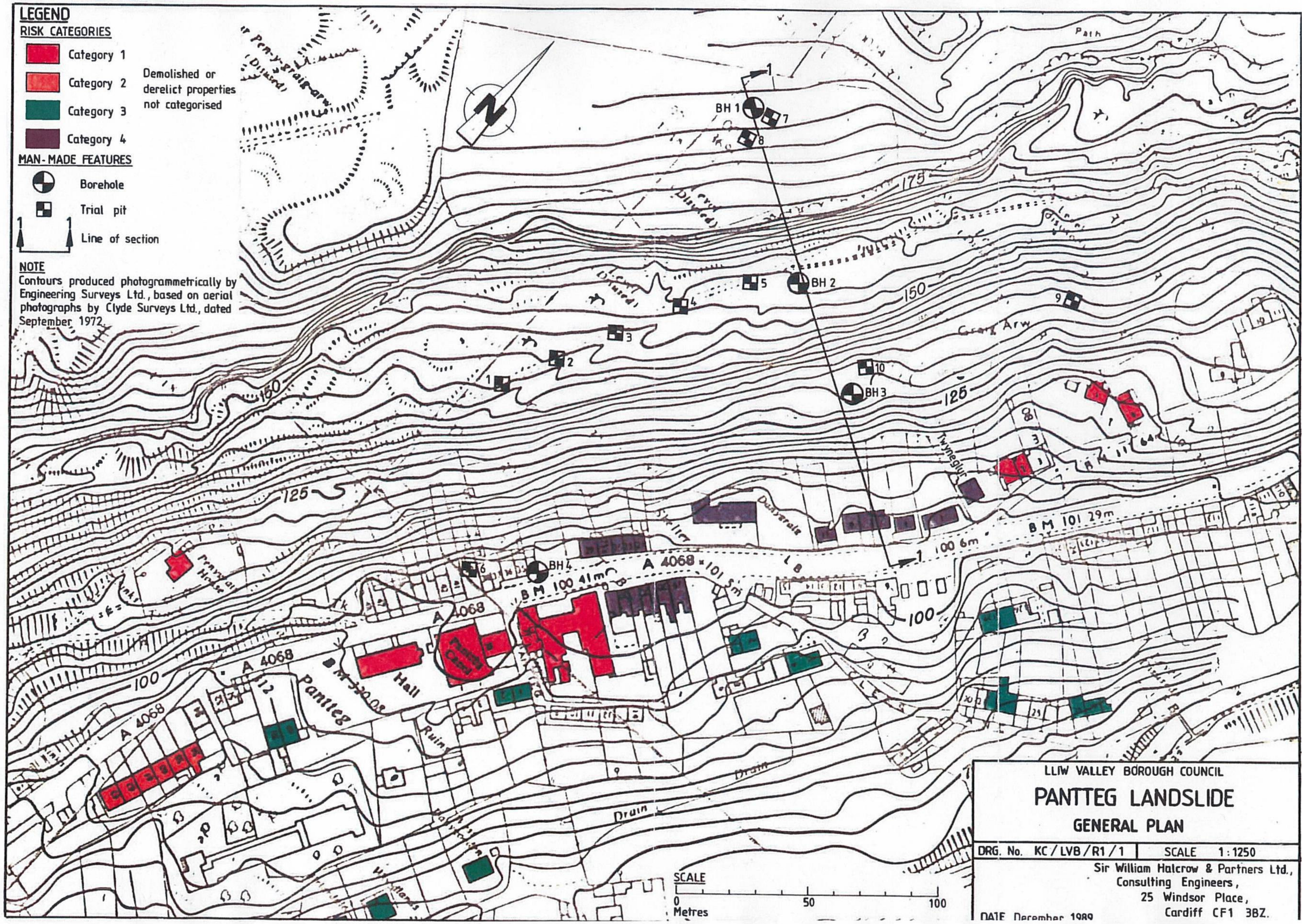
EX 10

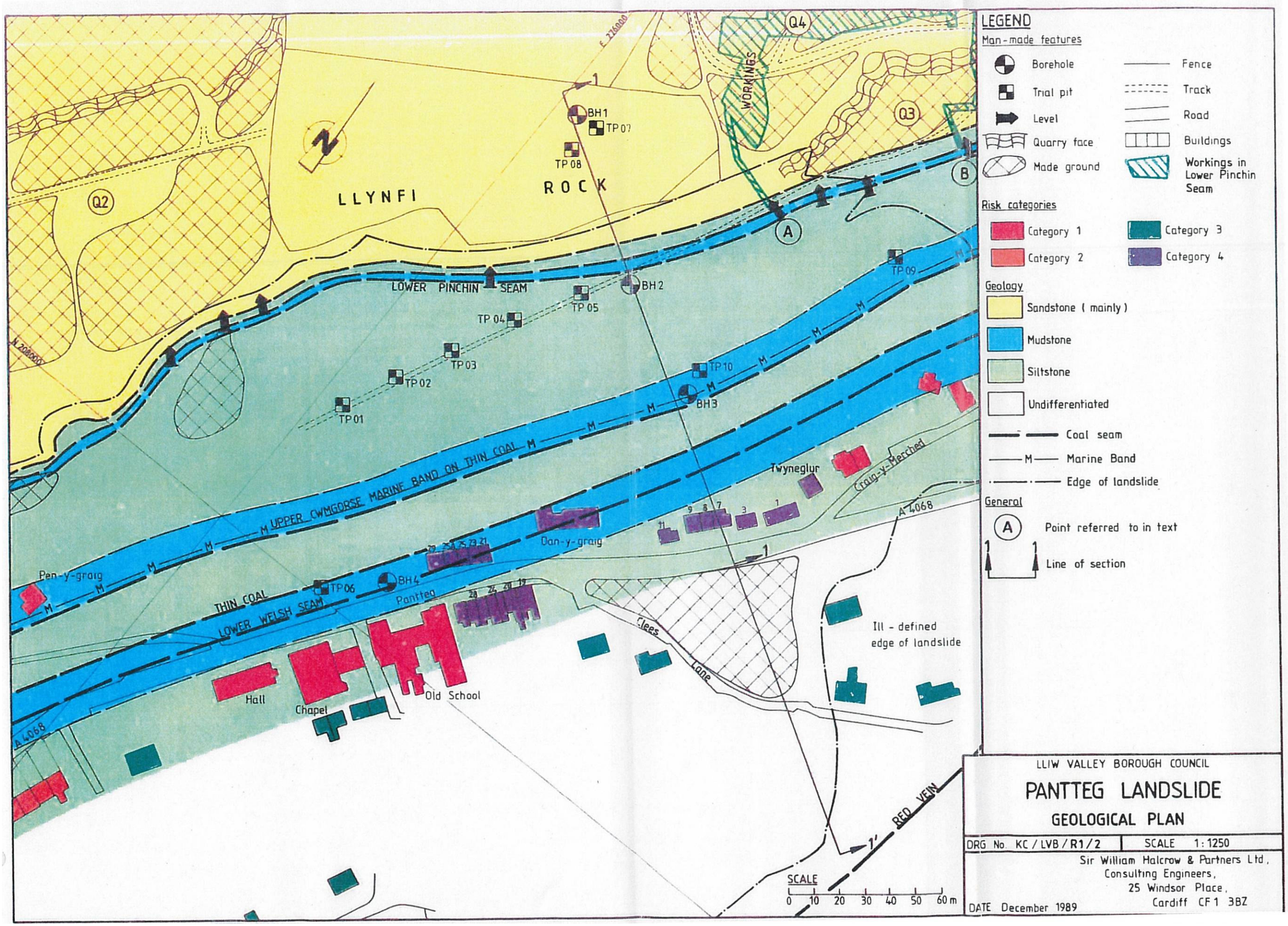
Appendix D Drawings

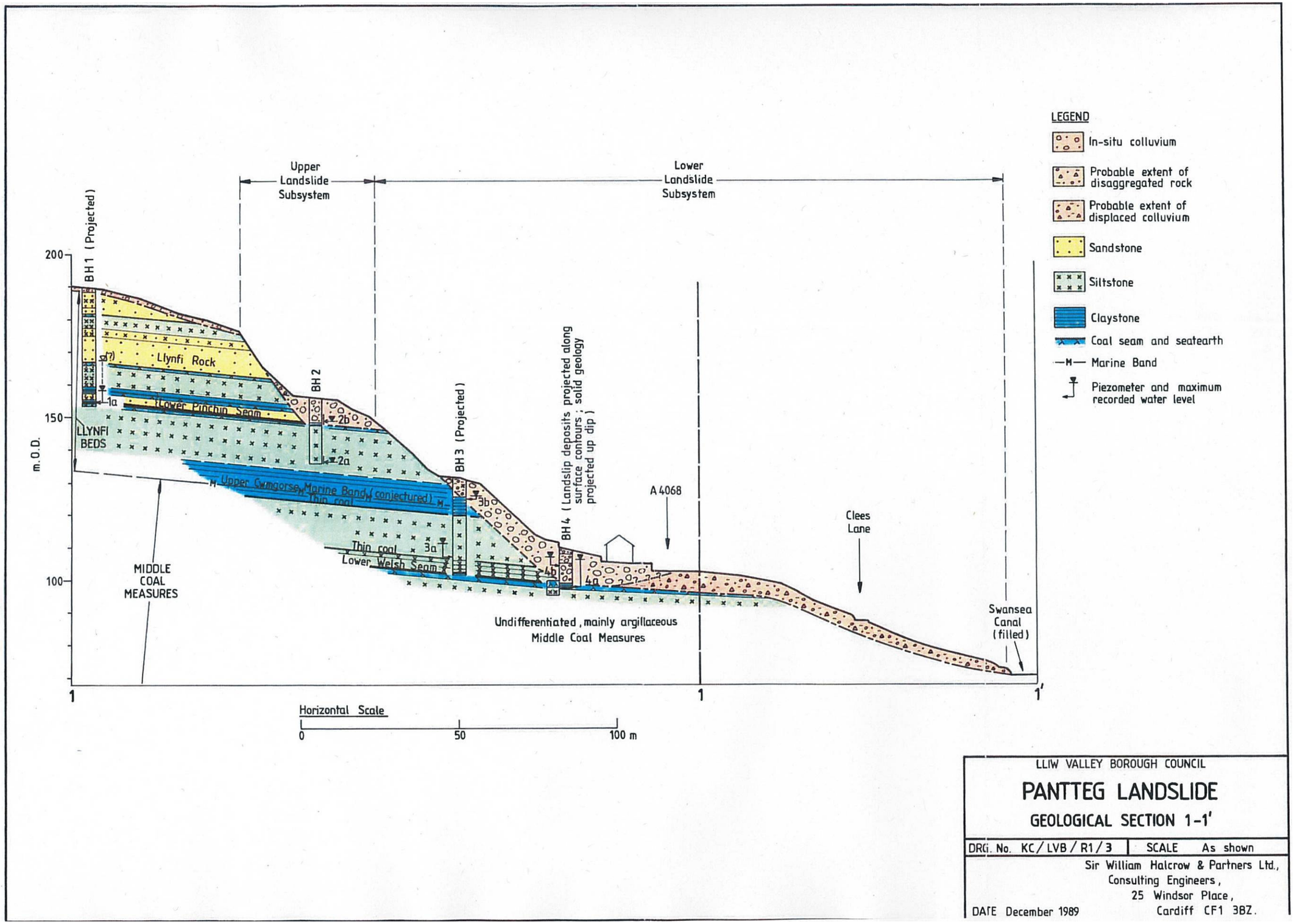
Drawings extracted from Halcrow 1989 Report [ref.2] of the Pantteg Area

Dwg No. KC/LVB/R1/1	General Plan
Dwg No. KC/LVB/R1/2	Geological Plan
Dwg No. KC/LVB/R1/3	Geological section 1-1'
Dwg No. KC/LVB/R1/4	Morthphology and Geomorphology

JACOBS


LEGEND
RISK CATEGORIES
Category 1
Category 2
Category 3
Category 4
Demolished or derelict properties not categorised
MAN-MADE FEATURES
Borehole
Trial pit
Line of section
NOTE
Contours produced photogrammetrically by Engineering Surveys Ltd., based on aerial photographs by Clyde Surveys Ltd., dated September 1972.
BH 1
BH 2
BH 3
BH 4
175
150
125
100
Craig Arw
A 4068
BM 100 41m
BM 101 29m
Hall
Pantteg
Drain
SCALE
0
50
100
Metres
LLIW VALLEY BOROUGH COUNCIL
PANTTEG LANDSLIDE
GENERAL PLAN
DRG. No. KC / LVB / R1 / 1
SCALE 1 : 1250
Sir William Halcrow & Partners Ltd.,
Consulting Engineers,
25 Windsor Place,
Cardiff CF1 3BZ.
DATE December 1989


E 226000
N 206000
Q2
Q3
Q4
LLYNFI
ROCK
WORKINGS
A
B
1
1'
BH1
TP 07
TP 08
BH 2
TP 09
TP 05
TP 04
TP 03
TP 02
TP 01
BH 3
TP 10
LOWER PINCHIN SEAM
M UPPER CWMGORSE MARINE BAND ON THIN COAL M
THIN COAL
LOWER WELSH SEAM
BH 4
TP 06
Pen-y-graig
Pantteg
Dan-y-graig
Twyneglur
Craig-y-Merched
A 4068
Clees Lane
Ill - defined edge of landslide
Hall
Chapel
Old School
RED VEIN
SCALE
0 10 20 30 40 50 60 m
LEGEND
Man-made features
Borehole
Trial pit
Level
Quarry face
Made ground
Fence
Track
Road
Buildings
Workings in Lower Pinchin Seam
Risk categories
Category 1
Category 2
Category 3
Category 4
Geology
Sandstone (mainly)
Mudstone
Siltstone
Undifferentiated
Coal seam
M Marine Band
Edge of landslide
General
A Point referred to in text
Line of section
LLIW VALLEY BOROUGH COUNCIL
PANTTEG LANDSLIDE
GEOLOGICAL PLAN
DRG No KC / LVB / R1 / 2
SCALE 1 : 1250
Sir William Halcrow & Partners Ltd.,
Consulting Engineers,
25 Windsor Place,
Cardiff CF1 3BZ
DATE December 1989



LLIW VALLEY BOROUGH COUNCIL

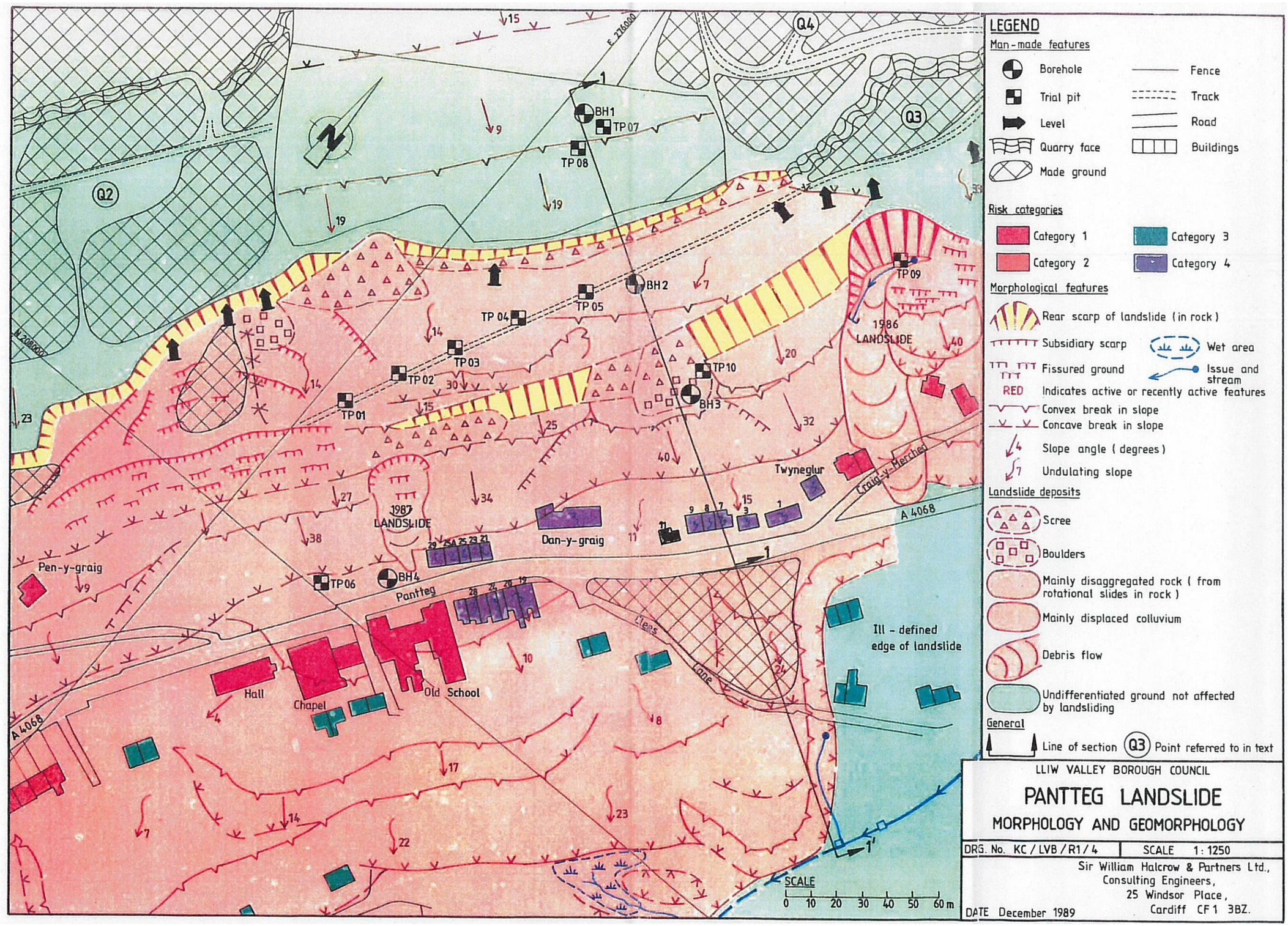
PANTTEG LANDSLIDE

GEOLOGICAL SECTION 1-1'

DRG. No. KC/LVB/R1/3	SCALE As shown

Sir William Halcrow & Partners Ltd.,
Consulting Engineers,
25 Windsor Place,
Cardiff CF1 3BZ.

DATE December 1989



LLIW VALLEY BOROUGH COUNCIL

PANTTEG LANDSLIDE

MORPHOLOGY AND GEOMORPHOLOGY

DRG. No. KC / LVB / R1 / 4	SCALE 1:1250

Sir William Halcrow & Partners Ltd.,
Consulting Engineers,
25 Windsor Place,
Cardiff CF1 3BZ.

DATE December 1989

Appendix E Site Inspection Survey Map

The enclosed drawing has been produced by Neath Port Talbot County Borough Council based upon information provided by Jacobs. The drawing has been reviewed by Jacobs for inclusion within this report.

NOTES

A1

1 THIS IS A C.A.D. DRAWING AND SHOULD NOT BE AMENDED BY HAND.

2 All dimensions in millimetres unless otherwise stated.

CLIFF LINE

AREA OF 2013 REGRADING WORKS

AREA OF EXTENSIONAL CRACKING

AREA OF DENSE VEGETATION ON STEEP SLOPES (UNABLE TO ACCESS)

Unoccupied Property

Rev	Details	Dr	Ch	Ap	Date

Client

APPENDIX E

SITE WALKOVER SURVEY MAP
JACOBS UK Ltd

REPORT No. B15974EX / 12858 / R5095

Neath Port Talbot
Castell-nedd Port Talbot
County Borough Council Cyngor Bwrdeistref Sirol
ENGINEERING AND TRANSPORT

JOHN S. FLOWER, B.Sc., C.Eng., C.Env., F.I.C.E, M.C.I.H.T
CORPORATE DIRECTOR OF ENVIRONMENT
THE QUAYS, BRUNEL WAY
BAGLAN ENERGY PARK
NEATH SA11 2GG

Project

PANTTEG/ GODRE-GRAIG
LANDSLIP AREA

SLOPE STABILITY REVIEW 2013

File No.	DC 5 / 16	Financial Code No.	26.007500.B054.262003		
Drawn	DTD	Checked	PGG	Approved	PGG
Date	10/13	Date	10/13	Date	10/13
Scales	1:2500				
Drawing No.	C42820 / 2013 / 02				

Drg. No.

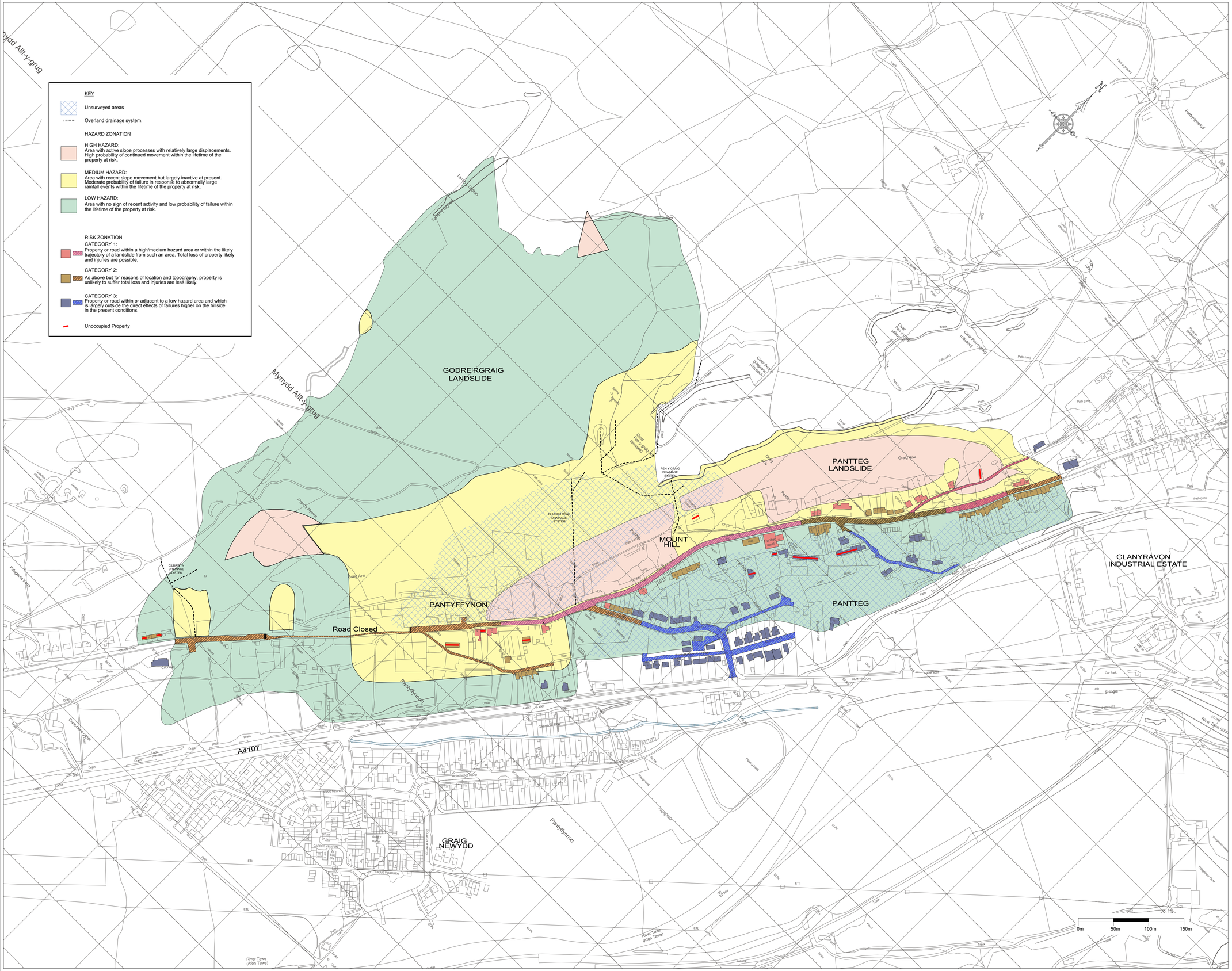
Project

S:\PETERS LANDSLIPS\PantegLandslipW2035.01\Jacobs Review 2013\C42820-2013-02.dwg

Appendix F Hazard and Risk Map

The enclosed drawing has been produced by Neath Port Talbot County Borough Council based upon information provided by Jacobs. The drawing has been reviewed by Jacobs for inclusion within this report.

THIS IS A C.A.D. PRODUCED DRAWING AND SHOULD NOT BE AMENDED BY HAND.



NOTES

1. All dimensions are in millimetres unless otherwise stated.

Rev	Details	Dr	Ch	Ap	Date
C	Areas Edited	DD	PGG	PGG	01 / 14
B	Map Updated	DD	PGG	PGG	01 / 14
A	New properties at Church Road	RPM	PGG	PGG	01 / 14

APPENDIX F

HAZARD AND RISK MAP
JACOBS UK Ltd

REPORT No. B15974EX / 12858 / R5095

Neath Port Talbot
Castell-nedd Port Talbot
County Borough Council Cyngor Bwrdeistref Sirol
ENGINEERING AND TRANSPORT

J. S. FLOWER, BSc, CEng, CEnv, FICE, MCIHT
DIRECTOR OF ENVIRONMENT
THE QUAYS, BRUNEL WAY
BAGLAN ENERGY PARK
NEATH SA11 2GG

Job Title

PANTTEG / GODRE'GRAIG

LANDSLIP AREA

SLOPE STABILITY REVIEW 2013

File No.	DC5/16	Financial Code No.	26.007500.B054.262003		
Drawn	DTD	Checked	PGG	Approved	PGG
Date	11/13	Date	11/13	Date	11/13
Scales	1:2500				
Drawing No.	C42820 /2013 / 01				C

Drg. No. C42820 /2013 / 01 C

Job Title

S:\PETERS LANDSLIPS\PantegLandslipW2035.01\Jacobs Review 2013\C42820-2013-01C.dwg