Appendix 6A

Geotechnical Desk Study

Welsh Government

Land at Nant Helen and Onllwyn Coal Washery

Geotechnical and Geoenvironmental Desk Study

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1 Introduction

The Welsh Government is considering the development of a rail testing facility in South Wales. The aspiration is for the development of a nationally significant rolling stock and infrastructure testing facility (Hereafter referred to as the 'proposed development').

Celtic Energy's Nant Helen site and Onllwyn Washery, immediately to the north of Onllwyn village, has been identified as a potential site for the proposed development. The site is currently an operational opencast coal mine and coal washery. The proposed development would allow the site to be re-purposed once the opencast mining activities have ceased and the site has been restored.

Arup have been commissioned by the Welsh Government to undertake a desk study assessment for the proposed site near Onllwyn in Powys. This desk study includes a summary of the site's history and ground conditions, including topography, geology, hydrogeology, hydrology and the coal mining legacy at the site. A preliminary conceptual site model and preliminary engineering assessment is then presented, together with a summary of the identified geotechnical and geo-environmental risks and opportunities and recommendations for further work.

It is envisaged that 7km of cuttings and embankments will be constructed in two loops. Based on the complex topography of the site, the cuttings and embankments will likely require significant cut (~30m) and fill (~40m) earthworks to form the embankment level.

In addition to the track loops, it is envisaged that a platform environment, facilities for rail storage, train decommissioning areas and educational activities will also be included as part of the developed works. These are likely to be located both within the Nant Helen site and within the portion of the site currently occupied by the Onllwyn Washery.

2 Sources of Information

The following sources of information have been reviewed in the preparation of this report:

- British Geological Survey (BGS) published geological and hydrogeological mapping
- British Geological Survey (BGS) online GeoIndex viewer
- Published environmental information (Lle)
- Information contained within the 2011 Nant Helen Extension Environmental Statement
- Historical aerial photographs (Welsh Government)
- Historical and present-day mapping sets (Groundsure)
- Opencast completion plans and select underground working abandonment plans (provided by Celtic Energy)
- Groundsure EnviroInsight and GeoInsight reports
- Coal Authority online viewer
- Coflein, National Monuments Record of Wales

3 Site Location and Description

The Celtic Energy Nant Helen site is located approximately 20km north-west of Swansea, immediately south of the Brecon Beacons National Park (refer to Figure 1). The plan area of the site covers approximately 500 hectares and is located between the A4109 to the south, and the A4221 to the north-east To the north the site is bounded by an area of forestry and by forestry access tracks from the Brecon Road to the north-west. The majority of the site is located within the Powys county boundary however the southern boundary of the site lies along the Powys/Neath-Port Talbot county border and a small portion of the site lies within the county of Neath-Port Talbot.

The site boundary is shown on Figure 2. For ease of identification, throughout the report the site (as a whole) has been split into the main and the "washery" portions. The main portion refers to the central body of the site which contains the proposed rail test track whereas, the "washery" portion refers to the extension of the site to the southeast incorporating the Onllwyn Washery.

The topography of the site is shown on Figure 2. The northern site boundary starts at ~250m AOD in the north-western corner before dropping in an easterly direction to ~195m AOD. The land then climbs back up to the eastern arc of the site boundary which approximately follows the 250m AOD contour line. The southern site boundary also approximately follows the 250m AOD contour line and locally drops to ~235m AOD. The western arc of the site boundary rises up from 250m AOD in the south to 270m AOD in the south-western corner.

The topography of the site generally rises inwards from the site boundary. The central portion of the site sits at around 280m AOD with localised peaks reaching approximately 295m AOD. The "washery" portion of the site sits lower than the main portion of the site at roughly 230mAOD.

The Celtic Energy Nant Helen site is currently being used as an active open cast coal mine. The extreme west of the site contains the Nant Helen Extension opencast working which is typically 150m lower than the surrounding ground surface at its deepest point (refer to Figure 2). A series of access tracks are present across the site. These access tracks connect the current open cast workings in the west with the Onllwyn Washery located in the east of the site. The washery site accessed from the A4221 via a separate entrance, and is comprised several buildings, conveyer belts and material sorting facilities.

The central portion of the main site is dominated by a large 'Overburden Storage Area'. The overburden storage areas are understood to be spoil heaps placed above the natural ground level. The maximum height of the spoil material is understood to be approximately 80m above the natural ground surface.

3.1 Site Walkover

A site walkover was undertaken by an Arup geotechnical engineer on 28th November 2018 with a representative from Celtic Energy. Pertinent site walkover photographs are presented in Appendix A which should be referred to throughout

this section. Refer to Figure 3 for the approximate locations of the site walkover photographs.

The images presented in Appendix A include Photograph 1 showing the large overburden storage area. Photograph 3 shows the current Nant Helen Extension opencast site. Photographs 3, 4, 5 and 6 show examples of the material excavated during the opencast mining activities.

Photograph 1 was taken facing approximately NNW and shows the southern face of the large overburden storage area centrally located within the site. Photograph 1 also shows the electricity pylons that cross the southern portion of the site; the route of which is indicated on Figure 3.

Photograph 2 was taken facing approximately eastwards and shows a small pond type feature which is located on the current proposed track route. The western slope of the large overburden storage area is shown behind the pond feature.

Photograph 3 was taken facing northwest and looks down into the current Nant Helen Extension opencast mine extent. The depth of the excavation is evident (~150m) and a large lake feature is present at the base of the excavation. Assuming backfilling activity has been undertaken as shown by the batter slopes shown on the right-hand side of the photograph.

Photographs 3, 4, 5 and 6 show examples of the material excavated during the opencast mining activities. The material shown is predominantly gravel sized with larger cobble and boulder sized inclusions. Evidence of fracturing is present on many of the larger inclusions. The material is anticipated to be mudstone/siltstone and is dark in colour. This material is anticipated to be the non-coal bearing arisings excavated during the opencast mining activity and is likely to be indicative of the material used to backfill the opencast sites post completion.

Photograph 5 is facing roughly eastwards and shows the coal haul route running eastwards towards the centrally located site compound and offices. The land rising to the south (right-hand side of the photo) is the northernmost extent of the overburden storage area. The current proposed track route is anticipated to run eastwards from this point running through the southern edge of the forestry shown on the left-hand side of the photograph.

Photograph 6 is facing approximately ESE and is located along the coal haul route. The photograph shows the various stockpiles either side of the roadway. From review of the site context figure provided by Celtic Energy (Appendix H), this area is the coal stocking area. The coal stocking area is located atop the backfilled extent of the original Nant Helen opencast site. The site compound and offices are located over the horizon shown on photograph 6.

Photograph 7 shows four cylindrical tanks located to the northwest of the site compound and offices. These tanks display flammable warning signs and are anticipated to be fuel tanks used for the various motorised plant vehicles. A large motorised plant vehicle is shown to be parked behind the tanks.

Photograph 8 was taken facing NW and looks out over the eastern half of the main portion of the site. The land is shown to rise gently towards the northwest

with the forestry that borders the northern half of the site shown to be present lining the horizon on the left-hand side of the photograph.

Photograph 9 is facing approximately eastwards and looks back towards the Onllwyn washery site. The washery infrastructure is shown in the background with a large pond shown in the foreground beyond the road.

Photograph 10 is facing NW and looks in towards the centre of the site. The photograph shows the eastern extent of the electricity pylons and the left-hand portion of the horizon marks the anticipated southern extent of the second Onllwyn opencast site (refer to Section 9).

4 Site History

Historical features and constraints have been identified through a review of historical mapping sets (1876 - 2019) and historical aerial photography (1945 – 2019). The mapping sets have been purchased from Groundsure and are referenced accordingly; the mapping sets cover a range of scales from 1:1,250 to 1:10,560. The aerial photographs have been acquired from Welsh Government and provide a higher level of detail for portions of the site covered. Current online aerially imagery has also been reviewed to supplement the historical sources. The mapping source material reviewed is presented within Appendix B.

In general, the site has been subject to extensive surface and sub-surface coal mining activities over the past century. The majority of relevant features and potential constraints identified are related to the site's coal mining legacy. A detailed review of mining activity is discussed in further detail within Section 9 of this report.

Table 1 below provides a summary of each individual historical source reviewed. Refer to Figure 4, Figure 8 and Figure 9 throughout.

Table 1 – Summary of historical features and constraints

Source	Notable features and alterations
1876 / 1877 Historical Maps	The Gwaunclawdd and Abercrave Collieries are shown to the north of the site with the latter shown to be located within the site boundary. To the south of the Abercrave Colliery, numerous 'Old Quarry' and 'Old Coal Level' features are shown to be located within an area which appears to have been heavily worked. The Neath and Brecon Railway (Junction Line) is shown to run along the northern boundary of the site following a rough east to west alignment. The "Junction Line" forms a network with the Neath and Brecon Railway main line (see paragraph below) and links the Collieries located to the north of Mynydd Drum (Abercrave & Gwaunclawdd) to the Onllwyn Colliery and washery site to the south of Mynydd Drum. To the south of the southern main site boundary, the Neath and Brecon Railway runs from southwest to northeast before crossing into the "washery" portion of the site. The majority of the southern portion of the main site is shown to be undeveloped moorland with localised marshy areas; the marshy areas feed several streams which flow in a southerly direction to converge with the River Dulais. A selection of cuttings and embankments, labelled as an "Old Tramway", is shown to cross the southern boundary of the site running along a rough east to west alignment. Based on review of

Source	Notable features and alterations
	the Transport Trust and Forest Fawr online sources, the Old Tramway believed to have originally formed part of the "Brecon Forest Tramroad". The portion of the tramroad that passes through the site was called the 'Claypon extension' and was constructed circa 1827. The extension linked the existing Brecon Forest Tramroad network, constructed circa 1819, to the "Drum Coal Levels" (located ~500m to the southeast of the site) and to the Swansea Canal. In 1859 the majority of the Brecon Forest Tramroad was incorporated into the Neath and Brecon Railway; however, the Claypon extension, which crossed Mynydd Drum, was abandoned. An 'Old Coal Level (Entrance)' is shown to be located close to the southern boundary of the site. Numerous 'Old Quarries' are located towards the centre of the site, although these are all minimal in size. The washery portion of the site is shown as predominantly undeveloped moorland. A tramway links the Onllwyn Colliery to the Neath and Brecon Railway main line which passes through the washery portion of the site. The tramway initially follows the same alignment (SW to NE) of the Neath and Brecon Railway before spurring off in an easterly direction once past the Onllwyn Station. The tramway then runs along the northern boundary of the washery site before turning to the south east and running along the north-eastern boundary of the washery site towards the Maes-y-marchog Colliery. The land to the north of the washery portion of the site is a marshy area marked as Gors Llwyn.
1901/ 1903 Historical Maps	The Abercrave Colliery has increased in size and an additional colliery, the International Colliery, is shown to be located approximately 100m to the west of the Abercrave Colliery. The area to the south of the Abercrave Colliery is still shown to be heavily worked. Approximately 500m to the east of the Abercrave Colliery an 'Old Tramway' is shown. The tramway links a selection of 'Old Levels' and a singular 'Air Shaft' to the Neath and Brecon Railway (Junction Line). These workings are not named and are not shown on the mapping from 1876/77. The Gwaunclawdd Colliery is now shown in a new location approximately 500m to the east of the original location. The original site now contains an 'Old Shaft' and an 'Old Quarry'. The southern portion of the main site has remained relatively unchanged. However, a tramway is now shown to links a singular coal level to the Dulais Colliery (marked as "Drym Colliery"); an air shaft, believed to be associated with the coal level, is shown to the north of the level (see Figure 8). The Onllwyn Colliery has expanded and moved location to be situated within the site boundary. The Dulais Colliery (marked as "Drym Colliery") is shown within the site boundary to the north of the Neath and Brecon Railway main line which still runs through the washery portion of the site. The tramway identified within the washery portion of the site on the 1877 mapping is still present. A selection of 'Old Coal Levels', 'Old Quarries' and an 'Old Coal Pit' (all not shown on the 1877 mapping) are now present.
1914 Historical Maps	The Abercrave Colliery is shown to have expanded eastwards with a new tramway linking to new drift mine located approximately 400m to the east of the main colliery site. The 'Old Tramway' linking to the 'Old Levels' and 'Air Shaft' identified on the 1901/03 mapping is no longer present. The 'Glynllech Colliery' is now shown immediately to the east of the 'Old Levels' with an associated tramway spurring from

Source	Notable features and alterations
	the colliery in a north-eastern direction linking to the Neath and Brecon Railway (Junction Line). The tramway identified in the southern portion of the main site is no longer present. The remainder of the southern half of the site has remained unchanged. The 'Drym Colliery' is now marked as the 'Dulais Colliery' and has grown considerably with multiple structures located to the north of the Neath and Brecon Railway. The majority of the washery portion of the site has remained unchanged.
1945 Aerial Photographs	Extensive earthworks and stockpiles are shown to be surrounding the collieries along the northern boundary of the site (Abercrave, International, Gwaunclawdd and Glynllech). Two distinct areas containing a number of depressions in the ground surface are shown on the aerial photograph in the southern portion of the site. These areas are in the same location as the coal levels and air shafts identified on the 1876/77 historical mapping sets. The frequency of the depressions is indicative of 'bell pitting' extraction methods refer to Figure 12 Extract from 1945 aerial photography showing potential 'bell pitting' 2 within Section 9.3. The washery portion of the site is shown to have been developed with numerous rail tracks spurring from the Onllwyn Station in an easterly direction. The tramway identified on earlier historical sources is still present. A number of large stockpiles/spoil heaps are shown to be present within the washery portion of the site and to the west of the Onllwyn Colliery.
1948 Historical Maps	The Glynllech Colliery is still shown however the tramway linking the colliery to the Neath and Brecon Railway (Junction Line) is no longer present; this suggests that the colliery is no longer operational. The Abercrave and International Colliery footprints have reduced in size and much of the interlinking rail tracks and tramways are no longer shown. The Gwaunclawdd Colliery is no longer shown. No changes noted within the southern portion of the main site. The Dulais Colliery is now labelled as disused and all the coal mining related infrastructure associated with the colliery that was previously shown is no longer present. The Onllwyn Colliery is still present. A 'Brickworks' is shown to be present within the washery portion of the site. The brickworks is located to the south of the existing rail tracks and assumed 'Washery' infrastructure. An 'aerial ropeway' is shown within the site and is believed to be associated with the spoil heaps shown to be present within the washery portion of the site.
1951 Aerial Photographs	The Abercrave and International Collieries are shown to be present and the area of land previously occupied by the Gwaunnclawdd Colliery has been completely cleared of coal mining infrastructure; the only evidence of the colliery that remains are the earthworks located immediately to the south. The Glynllech Colliery is no longer shown.

Source	Notable features and alterations
	The first evidence of opencast coal mining activity is shown to be present within the southern half of the main portion of the site. These workings appear to have been recently filled are anticipated to be the original Onllwyn opencast site. The workings are shown to intersect the "Old Tramway" identified on the 1876/77 historical mapping; two sections of cuttings along the tramway alignment appear to have been filled with spoil which anticipated to have arisen from two of the opencast sites shown. The Onllwyn opencast sites shown appear to coincide with the locations of the "dimpling" noted from the 1945 photography; as a result, the "dimpling" (possible bell pitting extraction) is no longer shown on the 1951 photography.
1965 Historical Maps	The Abercrave Colliery is still shown on the map, however many of the levels and drifts are labelled as 'disused' and the majority of rail and tramway infrastructure is no longer present. The infrastructure within the washery portion of the site has increased in size and the plan extent of the stockpiles/spoil heaps in the east has grown.
1975 Aerial Photographs	The land previously occupied by the numerous collieries located along the northern boundary of the site appears to have been completely reprofiled with no evidence of the collieries, or the worked land immediately to the south of the collieries, present. This is believed to be the result of the Abercrave/Gwaunton opencast coal mine (refer to Section 9.5). Evidence of earthworks associated with the construction of the A4221 are shown to be located along the north-eastern boundary of the main portion of the site.
1977 Aerial Photographs	A large opencast coal mine is shown to be present in the eastern half of the main portion of the site. This opencast site is anticipated to be the second Onllwyn opencast site and covers a much greater plan area than the original workings. The land to the southwest of the opencast site is covered with numerous stockpiles/spoil heaps. The A4221 is shown to have completed construction and borders the north-eastern boundary of the site. The Onllwyn Colliery is no longer shown to be present. A large stockpile is now shown to occupy the original colliery site. The Neath and Brecon Railway line is still present and links to an extensive network of sidings which spur eastwards into the washery portion of the site. The washery has increased in size and the numerous pond features, shown on the most recent aerial imagery, are now present. The area of land to the east of the washery appears to be in the process of being filled with numerous stockpiles/spoil heaps present.
1985 Aerial Photographs (Colour)	A distinct area of darker land is shown along the northern boundary of the site. This is anticipated to be associated with the backfilling of the Abercrave/Gwaunton opencast site; extensive forestry planting operations appear to have taken place within the areas which have been backfilled. The larger Onllwyn opencast site is shown to have been backfilled with numerous man-made drainage features shown to be present across the surface.
1987 / 1988 Historical Maps	The northern half of the main portion of the site is shown to be covered with forestry. A collection of disused levels and drifts are shown to be present. These are likely to

Source	Notable features and alterations
	have been associated with the Glynllech Colliery. The Onllwyn opencast site is labelled as disused workings. No other major observable changes are shown with regards to the south of the main portion of the site or within the washery portion of the site.
1989 Aerial Photographs	The main site compound is shown to be present centrally located within the main portion of the site. The first evidence of the Nant Helen opencast workings are shown to be present immediately to the west of the site compound. To the west of the opencast workings the "layer cake" overburden storage area is being formed; it is likely that the layer cake was formed with arisings from the original Nant Helen opencast workings. Numerous pond features are present along the southern face of the overburden storage area and along the eastern and western edges of the Nant Helen opencast excavation. From review of the Site Context figure provided by Celtic Energy, see Appendix H, these pond features are labelled as water treatment areas.
1995 Aerial Photographs (Colour)	The Nant Helen opencast excavation has progressed northwards with the existing void having been backfilled. The large overburden storage area, now located to the southwest of the opencast workings, is shown to have been completed to its present extent.
2006 Aerial Photograph (Colour)	The Nant Helen Extension opencast coal mine is shown to extend westwards from the Nant Helen opencast coal mine identified in the 1989 and 1995 aerial photographs. The original Nant Helen opencast void appears to have been filled and the surface is now covered with numerous stockpiles. An access track runs westward through the stockpiles from the site compound to the Nant Helen Extension workings in the west. The site of the original Nant Helen opencast appears to have been restored with a collection of small pond features and areas of vegetation present
2009 Aerial Photograph (Colour)	The Nant Helen Extension opencast coal mine has grown westwards and the original extent has now been partially backfilled with what appears to be site-won material. No other major changes are noted between the 2006 and 2009 aerial photographs.
2019 Online Aerial Imagery	The Nant Helen Extension opencast is shown to have reached its maximum extent. The extent of excavation shown on the 2006 aerial photograph has been backfilled and the majority of the 2009 extent has been partially filled with batter slopes falling westward into the open excavation. The 'washery' portion of the site is shown to contain a varied array of coal processing infrastructure with a limited network of rail lines running along an east to west alignment towards the north of the site. The land to the north and east appears to be artificially raised industrial scrubland with minimal vegetation cover. The land to the south of the washery has a higher degree of vegetation.

4.1 Summary

Although certain areas, particularly the area close to southern boundary of site, have been left relatively undeveloped, the majority of the site is shown to have been impacted by extensive coal mining activity. These activities include both

surface and sub-surface workings and have been identified from the earliest historical mapping to the present day.

Several historical collieries have been identified along the northern and southern boundaries of the site. The majority of the collieries were located on the lower slopes of Mynydd Drum and workings were accessed via both drifts and vertical shafts. The Abercrave and Gwaunclawdd Collieries were present on the earliest historical mapping from 1876/77 and the last evidence of the collieries disappeared following the absence of the Onllwyn Colliery on the 1977 aerial photography (refer to Section 9.4 for greater detail regarding underground mining).

The first evidence of opencast workings was identified on the 1951 aerial photography which showed workings believed to be associated with the first Onllwyn opencast site. The subsequent aerial photographs show evidence of the second Onllwyn, the Abercrave/Gwaunton, the Nant Helen and the Nant Helen Extension opencast sites. The depth and extent of the opencast sites appears to have increased from the shallow workings associated with the first Onllwyn opencast site to the deepest workings associated with the Nant Helen Extension works which are shown on the present day online aerial imagery.

Various rail tracks and tramways are shown to have crossed through and run along the boundaries of the site. The earliest of which was marked as an ‘Old Tramway’ on the historical mapping from 1876/77; from a review of information presented on the Transport Trust [19] and Forest Ffawr online sources [20], this tramway is believed to have formed part of the “Brecon Forest Tramroad”. The section that passes through the site was known as “Claypon’s extension” and was constructed circa 1827. The tramroad is a historically significant site and is a scheduled ancient monument alternatively known as “Tramroad at Ystradgynlais”.

A selection of other short tramways are shown to have been present within the site linking collieries like the Glynllech Colliery to the Neath and Brecon Railway (Junction Line).

The washery portion of the site has contained rail tracks/sidings and tramways since the earliest historical mapping and as the opencast coal mining activity increased towards the end of the 20th century the extent of coal mining washery infrastructure and stockpile/spoil heaps also increased.

5 Published Geology

The geology beneath the site has been interpreted through a review of published geological sources. These sources include the BGS 1:10,560 geological mapping (sheet SN 81 SW) [1], the BGS 1:50,000 geological mapping (Sheet 231) [2] and the BGS GeoIndex online viewer [3]. Refer to Figure 5 and Figure 6 throughout.

5.1 Made Ground

A region of artificial ground is shown to be present in the north of the site; based on review of documents provided by Celtic Energy, this is anticipated to be made ground associated with the backfilling of the Abercrave/Gwaunton opencast coal mine (refer to Section 9.5 for greater detail).

Although not shown on published geological sources, based on the known extent of opencast coal mining across the site, backfill made ground is anticipated to be encountered beneath much of the proposed track route. Based on observations made during the site walkover the material excavated during mining are generally granular (see Photographs 3, 4, 5 and 6).

5.2 Drift (Superficial Deposits)

Geological mapping of superficial deposits at 1:50,000 scale shows that the site is predominantly void of superficial material with only localised areas to the west and south of Devensian Till and an area of peat located centrally within the site. Deposits of Devensian Till and peat are also shown to be present beneath a small section of the washery portion of the site. The Devensian Till is noted to be of glacial origins and is labelled as boulder clay on the 1:10,560 geological map. Glacial till typically comprises a heterogenous mixture of clay, sand and gravel with large cobble and boulder inclusions of various size and shape (diamicton). The 1904 geological memoir for sheet 231 describes the glacial till deposits within the Dulais valley *"…Old Red* (sandstone) *in a stiff bluish matrix* (clay)*"* [4]. Peat typically comprises a partially decomposed mass of vegetation that has grown under anaerobic conditions, usually found in bogs or swamps.

It should be noted that the area of glacial till identified to the west of the site coincides with the known extent of the Nant Helen Extension opencast site (refer to Section 9.5). It is therefore likely that these deposits are no longer present and will have been incorporated within the extensive 'overburden storage areas' formed from the surplus material excavated during opencast mining activity.

The area of peat shown in the centre of the site is also unlikely to be present due to the fact that the plan extent of the peat coincides with the Nant Helen opencast site. It is not known whether these peat materials were stockpiled on site of disposed of offsite.

Given the location shown, the area of glacial till shown to the south is unlikely to have been impacted by the earthworks associated with opencast activities and is therefore likely to remain present.

The geological map shows glacial till deposits to be present in the eastern end of the washery portion of the site. Peat deposits are shown to encroach into the north of the washery site, but it is considered likely that these materials would have been removed from beneath developed areas.

5.3 Solid (Bedrock)

The majority of the site is underlain by solid geology of the South Wales Middle Coal Measures Formation. The remainder of the site is shown to be underlain by South Wales Lower Coal Measures Formation. The South Wales Coal Measures generally comprise rhythmic sequences of mudstones (commonly containing pyrite), siltstones, sandstones, grits, fireclays, seatearths and coals; the coals found in these measures tend to be amongst the thickest and most economically significant in South Wales. According to the geological memoir (Sheet Memoir 231) from 1988, nodular masses of pyrite, up to 0.15m thick, are often present within the Middle and Lower Coal Measures formations [5].

The Middle and Lower Coal Measures reach their maximum thickness of around 900m in the Swansea district and decrease in thickness towards the northeast and east with a thickness of around 425m near Merthyr Tydfil [5]. Based on the location of the site, and assuming a linear reduction in thickness, the thickness of the Middle and Lower Coal Measures Formations beneath the site is anticipated to be to the order of 700m.

Based on review of dip angles presented on the 1:10,560 geological mapping, the solid geology is anticipated to Have a regional dip in a west south-westerly direction at angles ranging from between 5^{o} and 15^{o} [1]. The sequence is folded with a syncline and anticline indicated to be present beneath the site and as a result of which the bedding dip angles will vary in these locations. Within the South Wales Coal Measures, there is the potential for instability within rock cuttings as a result of planar failure along bedding plans of weaker beds such as seatearths.

5.4 Linear Features

Five faults, three of which are named, have been identified to cross the site from review of published geological mapping. All of the faults are roughly aligned along a NNW to SSE alignment.

Refer to Figure 6 and Figure 11 throughout.

The easternmost fault, the Glyncorrwg Fault, is shown to pass through the washery portion of the site. The cross-mark on the 1:10,560 geological mapping indicates that the fault downthrows to the west [1]; the geological memoir for sheet 231 from 1904 suggests that the Glyncorrwg Fault has a downthrow of *"forty yards"* (~36.6m) [4]. Moving westwards, there is an unnamed fault (potentially associated with the Glyncorrwg Fault) which crosses into the eastern half of the main portion of the site that is also indicated to be downthrown to the west. The Chapel Fault is shown to cross through the eastern half of the site and is indicated to be downthrown to the east; the geological memoir for sheet 231 from 1904 suggests that the Chapel Fault is downthrown *"sixteen yards"* (~14.6m) eastwards [4].

To the west of the Chapel Fault is the Pwllau Bach Fault. The alignment of the Pwllau Bach Fault splits the main portion of the site roughly down the middle and

downthrows to the west. The downthrow is stated to be as much as *"eighty yards"* (~73.2m) within the 1904 geological memoir [4].

The Glyncorrwg, Chapel and Pwllau Bach Faults form part of a horst and graben formation which is shown to be located beneath the eastern half of the site. The final fault shown to cross into the site is also unnamed. The fault crosses into the north-western most corner of the main portion of the site and downthrows to the east.

Numerous coal seams are shown to outcrop within the boundary of the site. A review of the coal resource shown to be present beneath the site and the associated mining activities, both surface and sub-surface, is provided in Section 9 which focuses on mining.

6 Ground Conditions

The anticipated ground conditions beneath the site have been interpreted through review of borehole and trial pit logs from previously undertaken ground investigations. The logs have been sourced from information provided by Celtic Energy and BGS borehole scans accessed from the BGS online GeoIndex. The logs reviewed are provided within Appendix C and Appendix D.

The stratigraphy noted on each log is presented in Table 2 below before a summary of the anticipated ground conditions is provided. For the approximate locations of the borehole logs reviewed refer to Figure 5.

Table 2 – Borehole Logs from previous Ground Investigations

Reference	Stratigraphy (m bgl)	Groundwater
Completion plan vertical sections		
Onllwyn [1] (1949)	GL @ 261.2m AOD Base of Nine Feet Seam @ 258.0m AOD – Coal Seam (3.2m bgl) Base of Brass Seam @ 249.3m AOD – Coal Seam (11.9m bgl)	No groundwater remarks noted
Onllwyn [1] (1982)	GL @ 247.4m AOD Base of Upper Peacock @ 242.3m AOD – Coal Seam (5.1m bgl) Base of Peacock @ 232.5m AOD – Coal Seam (14.9m bgl) Base of Bluers @ 198.4m AOD – Coal Seam (49m bgl)	No groundwater remarks noted
Nant Helen Geotechnical Boreholes [2, 3]		
BH 2002 (1986)	GL @ 278.2m AOD GL – 0.5: Peat 0.5 – 2: Clay 2 – 3.1: Till 3.1 – 3.4: Mudstone 3.4 – 3.5: Coal 3.5 – 5: Mudstone	No groundwater remarks noted
BH 2005 (1986)	GL @ 280.6m AOD GL – 0.5: Peat 0.5 – 3.6: Till 3.6 – 4.5: Sandstone 4.5 – 4.75: Siltstone 4.75 – 6.8: Mudstone	No groundwater remarks noted
BH 2008 (1986)	GL @ 279.3m AOD GL – 0.5: Peat	No groundwater remarks noted

Reference	Stratigraphy (m bgl)	Groundwater
	0.5 – 1.0: Clay 1.0 – 3.6: Till 3.6 – 5.4: Mudstone	
BH 2009 (1986)	GL @ 282.5m AOD GL – 0.45: Peat 0.45 – 1.45: Clay 1.45 – 3.7: Till 3.7 – 5.7: Mudstone	No groundwater remarks noted
BH 2010 (1986)	GL @ 277.2m AOD GL – 0.2: Peat 0.2 – 1.05: Clay 1.05 – 2.4: Till 2.4 – 4.2: Mudstone 4.2 – 7: Siltstone 7 – 7.5: Sandstone	No groundwater remarks noted
BH 2011 (1986)	GL @ 271.7m AOD GL – 0.2: Peat 0.2 – 1.8: Clay 1.8 – 3: Mudstone 3 – 3.4: Siltstone 3.4 – 6.4: Mudstone	No groundwater remarks noted
BH 2013 (1986)	GL @ 263.4m AOD GL – 0.5: Peat 0.5 – 1.5: Clay 1.5 – 3.5: Till 3.5 – 4.1: Mudstone 4.1 – 4.5: Unknown strata 4.5 – 5.9: Mudstone	No groundwater remarks noted
BH 2018 (1986)	GL @ 253.0m AOD GL – 1.6: Peat 1.6 – 2.6: Clay 2.6 – 3.6: Till 3.6 – 5.7: Mudstone	No groundwater remarks noted
BGS Borehole Scans		
SN81SW30 (1989)	GL @ 236.48m AOD GL – 6: MADE GROUND: Loose to medium dense black sand and gravel mudstone with coal in a black silty clay matrix (colliery waste) 6 – 7: MADE GROUND: Soft grey brown mottled orange and black silty clay with much gravel of weathered sandstone and mudstone 7 – 8.05: Grey highlight to completely weathered silty MUDSTONE very weak laminated and micaceous 8.05 – 8.65: Dark grey IRONSTONE with some SILTSTONE 8.65 – 8.9: Light grey slightly to moderately weathered fine SANDSTONE, strong massive to occasionally cross laminated 8.9 – 9.6: Grey and light grey interlaminated moderately weathered silty MUDSTONE and sandy SILTSTONE, moderately weak occasional grey sandstone bands 9.6 – 11: Grey moderately weathered silty to very silty MUDSTONE, moderately weak 11 – 11.95: Dark grey slightly weathered silty SANDSTONE, weak. Thin sub horizontal laminations 11.95 – 14.2: Dark grey slightly weathered very slightly silty MUDSTONE moderately weak to weak laminated. Becoming very carbonaceous with depth. 14.2 – 15.03: Vitreous COAL 15.03 – 16.08: Dark grey to grey slightly weathered silty MUDSTONE, moderately weak many carbonaceous plant remains	Groundwater level ranging between 3.45m and 7.2m bgl during drilling

Reference	Stratigraphy (m bgl)	Groundwater
	16.08 – 19.7: Light grey slightly weathered clayey SILTSTONE moderately weak with occasional bands of thinly laminated silty mudstone. 19.7 – 21.65: Light to dark grey slighty weathered fine and medium SANDSTONE, strong massive with occasional cross bedding 21.65 – 22.3: Grey slightly weathered silty fine SANDSTONE moderately weak thin sub horizontal laminations very occasional plant remains and occasional sub vertical joints 22.3 – 25: Dark grey/black slightly weathered slightly silty MUDSTONE moderately to very weak. Often highly fragmented, often highly carbonaceous with occasional plant traces and occasional slickenside on joint surfaces 25 – 30: Open hole; Dark grey MUDSTONE	
SN81SW36 (1989)	GL @ 237.2m AOD GL – 3.2: MADE GROUND: Medium dense black sands and gravel of carbonaceous silty mudstone and coal with occasional black silty clay matrix 3.2 – 3.4: Firm brown organic CLAY with many rootlets and some peat 3.4 – 5.8: Firm to stiff grey brown mottled orange and black silty sandy CLAY with much gravel and occasional cobble of sandstone and mudstone and occasional coal fragments 5.8 – 6.7: Firm grey brown silty clay with mudstone fragments 6.7 – 7.2: Grey brown highly weathered silty micaceous MUDSTONE weak laminated and fragmented some iron staining 7.2 – 9: Grey moderately to slightly weathered SILTSTONE moderately weak laminated sub horizontal to massive iron staining on 45º joint planes 9 – 11.59: Grey moderately weathered slightly silty MUDSTONE weak often highly fractured 11.59 – 12.4: COAL with 45-60º slickensided joint surfaces 12.4 – 13: Grey slightly weathered silty MUDSTONE moderately weak massive many carbonaceous plant remains 13 – 18: Grey slightly weathered SANDSTONE and MUDSTONE 18 – 23: Dark grey slightly weathered SILTSTONE	Seepage of groundwater noted at 3.2m bgl at the base of the made ground Groundwater level ranging between 3.5m and 6.4m bgl during drilling
SN81SE4 (1977)	*GL not provided* GL – 0.6: MADE GROUND: Stiff grey/brown stony clay with sandstone cobbles 0.6 – 3.9: MADE GROUND: Firm dark grey silty clay with coal fragments 3.9 – 5: Stiff brown and grey mottled sandy CLAY with mudstone fragments	Groundwater struck at 1.5m bgl which rose to 1.3m bgl after 10 minutes
SN81SE5 (1977)	*GL not provided* GL – 0.2: Topsoil 0.2 – 0.5: MADE GROUND: Clay with coal wood and stones 0.5 – 1.5: MADE GROUND: Firm brown and grey mottled silty clay with sandstone and coal fragments 1.5 – 2.6: MADE GROUND: Stiff brown mottled silty clay with sandstone and coal fragments 2.6 – 3: MADE GROUND: Stiff dark grey shaly clay with coal fragments 3 – 4: Very stiff brown grey shaly CLAY with large angular sandstone fragments	Borehole dry
SN81SE6 (1977)	*GL not provided* GL – 0.1: Topsoil 0.1 – 0.7: MADE GROUND: Coal and clay 0.7 – 2.5: MADE GROUND: Firm grey/brown sandy stony clay with mudstone fragments and disseminated coal particles 2.5 – 4: Stiff grey/brown sandy stint CLAY with mudstone and large sandstone fragments	Groundwater struck at 3.0m bgl. Standing water level was measured at 1.6m bgl.
SN81SW37 (1991)	*GL not provided* GL – 0.8: Firm orange silty sandy CLAY with some fine and medium angular mudstone gravel and occasional coarse gravel and cobbles of sandstone	Slight groundwater seepage at 1.0m bgl within mudstone

Reference	Stratigraphy (m bgl)	Groundwater
	0.8 – 1.9: Highly weathered grey and orange laminated MUDSTONE, very weak. Generally recovered as angular gravel size fragments in a clay matrix	
SN81SW38 (1991)	*GL not provided* GL – 0.6: MADE GROUND: Grey shale and coal fragments with occasional brick and clinker 0.6 – 1.1: Firm grey and orange silty sandy CLAY with occasional fine gravel 1.1 – 1.8: Dark grey completely weathered MUDSTONE, recovered as clay with very occasional very weak mudstone lithorelicts 1.8 – 2: Highly weathered grey and orange laminated MUDSTONE, very weak. Generally recovered as angular gravel size fragments in a clay matrix.	Trial pit was dry throughout
SN81SW39 (1991)	*GL not provided* GL – 0.25: MADE GROUND: Grey shale fragments with occasional gravel 0.25 – 0.45: Stiff orange and grey silty sandy CLAY with occasional fine sandstone gravel and occasional boulder 0.45 – 1.5: Grey and orange highly weathered laminated MUDSTONE, very weak. Recovered as gravel size fragments	Trial pit was dry throughout

Notes

1. Detailed stratigraphy is not provided on the vertical sections shown on the opencast completion plans. Vertical sections have been reviewed to reveal the depth to coal seams.
2. The level of detail regarding 'Nant Helen Geotechnical Boreholes' is as presented on logs, refer to Appendix C. Logs reviewed to ascertain anticipated thicknesses of strata and depth to bedrock rather than for a detailed description of the materials encountered.
3. The boreholes appear to have been progressed in the same location as the large overburden storage area. Given the ground levels provided on the logs reviewed, it has been interpreted that these boreholes were progressed through the land currently underlying the large overburden storage area.

6.1 Interpretation

Made ground deposits are anticipated to be encountered beneath the majority of the proposed track route and within the washery portion of the site. The made ground backfill material anticipated to be present within the areas where opencast mining has been undertaken is likely to comprise gravel and cobble sized fragments of mudstone, siltstone and occasional sandstone.

Based on the descriptions provided in the logs reviewed, the made ground material anticipated to be encountered beneath the washery site is likely to comprise a mixture of varied granular backfill material within a cohesive clay matrix. The various gravel inclusions within the made ground were noted to be mudstone, sandstone, coal, clinker and wood. The thickness of this material is anticipated to range between 0.25m and 7m, although locally thicker deposits could be encountered in the locations of any stockpiles/spoil heaps within the washery site.

Natural superficial deposits of peat and glacial till are anticipated to be encountered beneath the southern portion of the site that has avoided opencast

activities and locally beneath the made ground materials anticipated to be encountered beneath the washery portion of the site.

In areas of the site that have not been subject to historical opencasting, peat deposits with thicknesses of circa 1-2m may be encountered. This material is anticipated to be soft/highly compressible and would need to be excavated and replaced with suitable earthworks fill or be subjected to ground improvement/treatment if it is encountered in the locations of proposed track alignment or the associated earthworks.

Glacial till deposits are also anticipated to be encountered in the locations that have not been subject to opencast mining activities within the main body of the site. The thickness of the glacial till material materials is likely to be limited (~3m) and discontinuous. No detailed descriptions of the glacial till material encountered were provided on the logs reviewed . Based on review of the published geological sources, glacial till typically comprises sand, gravel and cobble inclusions within a clay matrix.

Firm to stiff grey/brown clay with various mudstone, siltstone and sandstone gravel inclusions was encountered beneath the made ground deposits within the washery portion of the site. Based on the description and the published geological mapping, these materials are anticipated to be glacial till. Where encountered, the glacial till material beneath the washery portion of the site ranged between 0.2m and 2.4m thick. In some locations within the washery portion of the site, no natural superficial materials were encountered; in these locations the made ground material (described above) was encountered directly overlying the weathered bedrock.

As a result of the historical opencast workings within the site area, the depth to rockhead will vary greatly depending on location. Within the areas of the main site that have not been subject to opencast mining, the depth to rockhead is anticipated to be relatively shallow, with recorded depths ranging between 1.8m and 3.6m. However, in the locations that have been subject to opencast activity and have since been backfilled, the depth to rockhead could vary significantly over short distances (as detailed above). The bedrock material is anticipated to comprise interbedded mudstones and siltstones with occasional sandstone bands. The detailed descriptions from boreholes progressed within the washery portion of the site suggest that the mudstones and siltstones are slightly to moderately weathered and are moderately weak to strong. The materials are generally grey to dark grey in colour and occasionally micaceous. Where encountered close to surface, bedrock was recovered as highly weathered fragments of mudstone and sandstone within a clay matrix. Given this description, it is likely to be difficult to distinguish between the weathered head of bedrock and the overlying Glacial Till material.

From review of the vertical sections presented on the opencast completion plans for the Onllwyn site (1949), the base of the Nine Feet and Brass seams were encountered at 3.2m and 11.9m bgl ground level respectively. In addition, reference to the base of the Upper Peacock and Peacock seams were shown to have been encountered at 5.1m and 11.9m bgl respectively on the vertical section presented on the opencast completion plan for the Onllwyn site (1982). For

further detail regarding coal mining activity and the risk of shallow workings being present, reference should be made to Section 9 of this report.

Groundwater remarks were only provided on the logs reviewed within the washery portion of the site. The logs for the two deep boreholes reviewed within the washery portion of the site provided no indication of distinct groundwater strikes; however, the measured standing water level ranged between 3.45m and 7.2m bgl. Slight seepages and groundwater strikes were presented on the other logs within the washery portion of the site with some as shallow as 1.0m bgl. A detailed review of the groundwater beneath the site is provided in Section 8.3.

7 Hydrology

The hydrological features that pass through and surround the site have been identified through review of aerial online imagery and through review of the Groundsure EnviroInsight report (refer to Appendix E for the Groundsure report). The flow direction of the watercourses has been determined through interpretation of contours presented on the OS mapping covering the site area.

Figure 7 shows the location of identified hydrological features.

7.1 Watercourses

The site overlaps with three principal river catchments. The northern half of the main portion of the site sits within the Tawe catchment and contains several small unnamed streams which drain in a northerly direction towards the River Tawe. The River Tawe is the largest watercourse within the vicinity of the site and flows roughly from east to west approximately 500m to the north of the site boundary.

The Nant Llech, a tributary of the River Tawe, flows from east to northwest where it feeds into the Tawe and passes within 300m of the north-eastern site boundary. The Nant Llech is also an SSSI (refer to Section 10). A collection of small unnamed stream features to the northeast of the main portion of the site are shown to drain in a north-easterly direction towards the Nant Llech.

The southern half of the site sits within the Dulais catchment. The River Dulais flows roughly from east-northeast to west-southwest and runs through the washery portion of the site and along a portion of the south-eastern boundary of the main site.

The Nant Ystalwyn, a tributary of the Dulais, is shown to be fed by a selection of ponds which are located at the base of the large overburden storage area which is centrally located within the body of the main site. These ponds have been identified as water treatment areas and are fed by the drainage features present on the southern face of the large overburden storage area.

A collection of other tributary streams which originate within the central portion of the site flow in a southerly direction to their respective convergences with the River Dulais.

A small portion of the eastern half of the main portion of the site is shown to sit within the Pyrddin catchment. However, from review of OS mapping contours and the Groundsure EnviroInsight report, the drainage features within this portion of the site are anticipated to contribute to flows within the Dulais and not the Pyrddin (located ~1km to the east of the eastern site boundary). The drainage features identified appear to be man-made and initially flow in an easterly direction. Once they pass beneath Onllwyn Road the direction of flow turns south-westwards and runs parallel to the Onllwyn Road before feeding into a collection of ponds within the washery portion of the site. These ponds are located at the apparent source of the River Dulais and based on contours in the area are likely to feed into the flows within the Dulais.

One unnamed stream is shown to be located to the south of the washery portion of the site. From review of information presented within the Groundsure EnivoInsight report, this stream flows in an easterly direction before being culverted beneath the A4109 that borders the washery site to the south. The stream is then shown to re-emerge within the washery site before passing through another culvert beneath a section of the washery site. The stream eventually converges with the Camnant which in turn is a tributary of the Pyrddin.

As shown on the 'Site Context' figure provided by Celtic Energy (refer to Appendix H), several small pond features are shown to be located within the boundary of the site. Most of these appear to be 'water treatment areas', refer to Figure 7.

Through consultation with Celtic Energy it is understood that the easternmost water treatment area comprises ponds which are lined with a plastic liner. The water treatment areas that lie at the southern base of the large overburden storage area were constructed in 'virgin ground' and are possibly clay lined/sealed; if un-lined, it is likely that water is retained within these features due to the cohesive nature of the glacial till likely to be present in the area.

In addition to the water treatment areas, a collection of pond features are shown to be present in the area of 'restored land' above a portion of the Nant Helen opencast workings. It is understood that these ponds are an attempt to re-naturalise and create an ecological habitat post backfilling and are possibly lined with low permeability/cohesive materials.

8 Hydrogeology

This section of the report provides details on the anticipated hydrogeological regime beneath the site. Published hydrogeological sources have been reviewed alongside the Groundsure Report purchased for the site and data provided by Celtic Energy regarding groundwater levels beneath the site.

8.1 Hydrogeological Mapping

The information presented below has been based on review of the BGS 1:125,000 Hydrogeological Map of South Wales [6].

8.1.1 Drift (Superficial Deposits)

Till is a variable deposit of boulder clay and morainic drift. The principal lithology is unsorted stones of gravel, cobble and boulder within a silty clay matrix; however, in places lenses and more continuous bands of stratified sand and gravel are anticipated to be present. These predominantly granular lenses can act as localised perched aquifers however the main hydrogeological significance of till deposits is in limiting recharge to, and confining water within, underlying formations.

8.1.2 Solid (Bedrock)

The coal measures likely to be encountered beneath the site comprise rhythmic sequences of mudstones, siltstones, sandstones, grits, fireclays and coals. The South Wales Upper Coal Measures Formation (not shown to be present beneath the site) is known to contain large quantities of groundwater and form a multi-layered aquifer system with separate water bodies found within each sandstone horizon. The Middle and Lower Coal Measures (shown to be present beneath the site) tend to have lower porosities than the overlying Upper Measures with the highest values of porosity occurring in areas of intensive folding and faulting. However, the extensive disturbance and subsidence caused by mining in the South Wales region has resulted in hydraulic conductivity between the sandstone horizons comprising the South Wales Upper Coal Measures Formation and, locally, hydraulic conductivity exists between the Upper and Middle/Lower Coal Measures Formations.

The groundwater within the Middle and Lower Measures tends to contribute towards baseflow of rivers and usually emerges as springs at the bases of the subordinate sandstones. Groundwater yields from the Middle and Lower Coal Measures rarely exceeds 1l/s.

8.2 Aquifer Designations

The aquifer designations of the various geological strata identified to be present beneath the site have been ascertained through review of the Groundsure EnviroInsight report (refer to Appendix E).

The glacial till deposits shown to be present in the southern and western portion of the site are designated as a ‘Secondary Aquifer’. A ‘Secondary Aquifer’ designation is attributed to a stratum where it has not been possible to differentiate between a ‘Secondary (A)’ or ‘Secondary (B)’ designation. A ‘Secondary (A) Aquifer’ refers to a stratum defined as *“permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers”*. Whereas, a ‘Secondary (B) Aquifer’ refers to a stratum defined as *“predominantly lower permeability layers which may store and yield amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering”*. As identified on the hydrogeological mapping, granular lenses of sands and gravels within glacial till deposits can occasionally act as aquifers however, due to the cohesive nature of clays that are typical of glacial till, till deposits predominantly limit recharge to

and confine groundwater within underlying permeable stratum. It is therefore unlikely that the glacial till deposits located to the south of the site will form part of a large aquifer.

The deposits of peat shown to be present within the site are designated as 'unproductive strata'. Unproductive strata are defined as *"rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow"*.

The South Wales Coal Measures Formations (both Middle and Lower) shown to be present beneath the entirety of the site are both designated as 'Secondary (A) Aquifers' which are as defined above.

No principal aquifers are located beneath the site.

8.2.1 Abstraction Licenses

From review of the Groundsure EnviroInsight report, a singular groundwater abstraction license pertaining to a groundwater abstraction point ~800m to the northeast of the north-eastern boundary site is present. According to the date within the Groundsure report, this groundwater abstraction license is no longer active and the water abstracted was used for 'General Farming and Domestic' purposes.

However, it should be noted that opencast dewatering operations are known to be in operation which will be artificially lowering the groundwater level in the vicinity of the Nant Helen Extension opencast site.

A total of eight surface water abstraction licenses are held within a 700m radius of the northern boundary of the site. Six of these licenses pertain to abstraction points along the River Tawe or unnamed tributaries of the Tawe and are all designated as 'historical' suggesting that the licenses are no longer in effect. The remaining two surface water abstraction licenses pertain to two abstraction points from a reservoir at Gwaunclawdd Farm (not covered on the figures). These are also noted as 'historical' which suggest the licenses are no longer in effect.

8.3 Groundwater Levels

The groundwater levels beneath the site have been interpreted through review of ground investigation logs held by the BGS and through review of documents provided by Celtic Energy. It should be noted that the groundwater data presented on the logs held by the BGS is limited in nature and only pertains to the washery portion of the site.

Groundwater remarks presented on the BGS logs reviewed suggests that the groundwater level within the washery portion of the site sits between 3.45m and 7.2m below ground level. Shallower strikes and slight seepages were also noted as shallow as 1.0m bgl.

No indication of groundwater strikes were provided on the logs reviewed within the main body of the site. However, within the Environmental Statement submitted for the expansion of the Nant Helen Extension opencast site in 2011,

details regarding groundwater levels in the locale of the opencast area were provided (refer to Appendix H). It should be noted that these boreholes were not located within the boundary of the site.

Extensive exploratory drilling was undertaken by British Coal in the late 1990s in the location of the Nant Helen Extension opencast. It should be noted that these boreholes are located to the west of the western site boundary and do not pertain to the site directly. The boreholes were progressed through the known workings within the "Nine Feet" and "Brass" seams and the water levels within each were recorded. The groundwater level within these workings was recorded to be standing at approximately 126m AOD beneath the easternmost extent of the Nant Helen Extension opencast site and approximately 100m AOD at the westernmost extend of the Nant Helen Extension opencast site (refer to Appendix H). Based on current LiDAR elevation data, this would put the groundwater level between ~170m below current ground level (east) and ~50m below current ground level (west); the disparity in these levels is due to the existing Nant Helen Extension void in the west and the overburden storage area to the east.

These levels are corroborated by two piezometers which were also installed by British Coal during the ground investigation in the 1990s. These piezometers indicate that the groundwater level to the west of the Nant Helen Extension site was between 109m AOD and 99m AOD (refer to Appendix H).

Through consultation with Celtic Energy, it has been determined that current dewatering operations within the Nant Helen Extension opencast site aims to maintain the water levels at approximately 100m AOD. As highlighted in the Environmental Statement for the Nant Helen Extension opencast, the lowest projected level of excavation within the Nine Feet seam could be as low as 76m AOD (refer to Appendix H). As dewatering would be required to reach this depth, it is likely that the groundwater level would be locally reduced to a similar level. Post completion of opencast excavation in the area it is possible that the groundwater levels will re-bound to a similar level that was encountered within the boreholes progressed during the British Coal ground investigation in the 1990s (between ~100m AOD and ~120m AOD).

In addition, there are numerous adits that allowed access to workings within the Nine Feet and Brass seams to the west of the site. The lowest of which, the Cwm Du adit, underdrains the opencast workings within the Nant Helen Extension site. The Cwm Du adit has an invert level of 93.6m AOD where it discharges to the River Tawe (refer to Appendix H).

The hydrogeological regime beneath the site is anticipated to be complex and highly varied across the site. As highlighted in the 2011 Environmental Statement, there is evidence that the Nant Helen Extension site is under-drained by existing adits. This is likely to also be the case for the other areas of opencast working which have excavated through underground workings in the past; the groundwater levels within these regions is likely to be heavily dependent on the outflow capacity of the adits and secondary permeability of the underlying bedrock. In order to gain an appreciation for the groundwater levels in the various areas of opencast, identification of the likely under-draining adits (potentially through review of a comprehensive set of mine abandonment plans and/or a future site

visit) coupled with deep intrusive ground investigation including subsequent groundwater monitoring would likely be required.

It should also be noted that there are numerous surface water features that appear to originate within the site, particularly in the southern half. The levels (~250m AOD) of the ponds and the headwaters of the streams are unlikely to represent an overall piezometric surface for the site and instead are likely to represent locally perched groundwater controlled by areas of geology with low permeability (e.g. shallow impermeable bedrock or cohesive superficial deposits (both natural and made ground)).

9 Coal Mining

The entirety of the proposed site is situated within a Coal Authority 'Development High Risk Area'. A 'Development High Risk Area' is defined as an *"area which contains one or more recorded coal mining related features which have the potential for instability or a degree of risk to the surface from the legacy of coal mining operations"* [8]. These *"features"* typically include mine entries (shafts and adits) and shallow coal workings (recorded and probable).

New development in areas defined as high risk needs to demonstrate that the development will be safe and stable taking due account of former coal mining activities. This section of the report aims to highlight the particular features and constraints associated with mining activities in the area and identify 'risk zones' along the proposed route where the risk of subsidence on account of shallow workings is considered greatest. The features and risk zones are marked on Figures 8 and 9 which should be referred to throughout.

The sources reviewed during the preparation of this report are presented in Section 2 above; however, with regards to the information presented in this section of the report it should be noted that the basis of many of the findings is sourced from primary data sources such as BGS geological plans (various scale ranges), historical mapping sets and historical aerial imagery. The findings presented within the primary data sources have then been supplemented with data from secondary sources such as Coal Authority data and records provided by Celtic Energy.

9.1 Outcrops

As identified in the Published Geology section above, the site is primarily underlain by South Wales Middle and Lower Coal Measures Formations. Numerous coal seam outcrops associated with the aforementioned formations, both observed and inferred, have been identified from review of BGS published geological sources (refer to Figure 6). It should be noted that there is a discrepancy between the seam outcrops shown on the BGS published geological mapping and the seam outcrops shown on the Coal Authority online viewer. As the BGS published geological mapping is considered to be the primary data source, the locations of the seam outcrops shown on the BGS published geological mapping have been assumed to take precedence within this report.

The site is roughly split in half by the Pwllau Bach Fault along a north to south centrally located axis. Significant outcropping of seams within the South Wales Middle Coal Measure Formation is shown to the west of the Pwllau Bach Fault on the published geological mapping sources. The "Soap" seam is shown to outcrop along an east to west alignment from the Pwllau Bach Fault in the east to the site boundary in the west. Moving down through the Middle Coal Measures sequence, with the outcrops progressing northwards, and following a similar alignment, are shown for the "Stwrin", "Rock", "Little", "Four Feet", "Nine Feet" and "Brass" seams. To the north of the "Brass" seam the outcrop of the Amman Marine Band is shown to be located which marks the boundary between the Middle and Lower Coal Measures Formations. No outcrops are shown in the southern portion of the site to the west of the Pwllau Bach Fault. This is likely due to the dip of the solid geology (5^{o} – 15^{o}, WSW – SW) shown on the 1:10,560 geological mapping and the similar dip of the topography also towards the southwest.

Between the Pwllau Bach Fault and the Chapel Fault, the observed and partially inferred outcrops of the "Nine Feet" and "Brass" seams are shown on the published geological mapping reviewed. The outcrops of both are shown to follow a north to south alignment before turning 90^{o} to run along an east to west alignment. To the south of the site within the bounds of the Pwllau Bach and Chapel faults, the inferred and partially observed outcrops of the "Cornish", "Lower Eighteen Feet" and "Stwrin" are shown to be present.

To the east of the Chapel fault (downthrow to the east) the "Nine Feet" and "Brass" seam outcrops are once again shown to be present within the site boundary. The alignments of both are shown as observed and are believed to have been mapped during the opencast mining activity located in the eastern half of the main portion of the site. The outcrops of the "Cornish" and "Stwrin" seams are shown to be located to the south of the site; the "Lower Eighteen Feet" outcrop is not shown to the east of the Chapel fault and instead the outcrops of the "Lower Four Feet" and "White Four Feet" seams are shown to be located between the outcrops of the "Cornish" (north) and "Stwrin" (south).

To the north of the Chapel fault in the north-eastern corner of the main portion of the site, the outcrops of the "Upper Bluers", "Middle", "Lower" and "Bryn" seams are shown to be present situated along an east to west alignment. An anticlinal axis is shown to manipulate the alignment of the "Upper Bluers" seam outcrop. All of these outcrops refer to seams located within the South Wales Lower Coal Measures Formation.

To the east of the Glyncorrwg Fault the inferred outcrops of the "Upper Bluers", "Grey" and "New" coal seams are shown to be present beneath the washery portion of the site. These inferred outcrops are shown to be situated along an approximate southeast to northwest alignment.

Through review of the BGS geological memoir for the site area (Sheet Memoir 231) and the Nant Helen old workings file provided by Celtic Energy, the anticipated sequencing of the seams within each formation has been determined and is presented in Table 3 below. In addition, from review of the various sources, inconsistency regarding naming of the various seams has been noted and so the other names (and deviations of the same seam, e.g. "Four Feet" and "Lower Four

Feet") associated with each seam are also noted in Table 3. Typical seam sections have been identified through review of the Nant Helen old workings file provided by Celtic Energy.

Table 3 – Interpreted coal seam sequencing

Seam	Other names	Typical seam section
South Wales Middle Coal Measures		
Soap	Two Feet-Nine	-
Stwrin	Two Feet-Nine	-
Four Feet	Upper Four Feet, Lower Four Feet, White Four Feet, White, Stwrin	0.9m
Eighteen Feet	Lower Eighteen Feet, Six Feet, Black	-
Cornish	Red Vein, Two Feet	0.76m
Harnlo	-	-
Nine Feet	Big	2.7 – 3.0m
Brass	Bute, Peacock	0.9 – 1.4m
South Wales Lower Coal Measures		
Yard	Lower Peacock, Lower Brass	-
Bluers	Blewers, Upper Bluers, Lower Bluers, Seven Feet	0.6 – 0.85m
Rhyd	Five Feet, Little Brass	0.75m
Grey	Gellideg	0.66m
Middle	Gellideg	0.63m
New	Lower	0.69m
Bryn	Gnapiog	0.5m

9.2 Collieries

The following information for each of the identified collieries has been gathered from the Welsh Coal Mines website [9]. The information contained is not necessarily complete but identifies the seams worked by each colliery and provides information regarding years of operation. A short paragraph is provided on each colliery before the seams worked are listed; the seams are listed from shallowest to deepest based on published geological sequencing.

The approximate locations of each colliery are shown on Figure 4. The locations of the collieries have been determined through a review of historical mapping and photographic sources and not from information presented on the Welsh Coal Mines website.

Abercrave Colliery

The Abercrave Colliery was opened in 1872 and predominantly worked the "Eighteen Feet" seam and lower measures seams beneath the site. By 1923 the colliery was working the "Big Vein" (also known as "Nine Feet"), "Four Feet" and "Peacock" seams. The Abercrave Colliery was closed in 1967 [9].

Operational years: 1872 - 1967

Seams worked:
Middle Coal Measures
Four Feet
Eighteen Feet
Big (Nine Feet)
Peacock (Brass)

Lower Coal Measures
*Lower measures seams**

**no distinction between indivual seams within the Lower Coal Measures is provided in the source material.*

International Colliery

Records suggest that the International Colliery was opened in 1893 and was operated by the French Anthracite Company. The colliery is shown to have worked the "Four Feet", "Nine Feet", "Peacock" and "White" seams. The International Colliery was absorbed into the Abercrave Colliery in 1913 and both were eventually closed in 1967 [9].

Operational years: 1893 - 1913

Seams worked:
Middle Coal Measures
White (Four Feet)
Nine Feet
Peacock (Brass)

Gwaunclawdd Colliery

The Gwaunclawdd ("Gwaun Clawdd" or "Gwaun-y-clawdd") Colliery was opened in 1864 as an anthracite drift mine. The colliery produced anthracite from the "Big" (also known as "Nine Feet"), "Lower", "Brass" and "Four Feet" seams. The colliery was closed in 1938 [9]. From review of historical mapping sources, the Gwaunclawdd Colliery moved from its original site to a new site approximately 500m to the east between 1877 and 1903, refer to Figure 4.

Operational years: 1864 - 1938

Seams worked:
Middle Coal Measures
Four Feet
Big (Nine Feet)
Brass

Lower Coal Measures
Lower (Gellideg)

Onllwyn Colliery

Developed in the 1840's, the Onllwyn Colliery was originally a collection of drift mines situated in the upper Dulais valley working the "Big" (also known as "Nine Feet"), "Red Vein" and "Peacock" seams. Detail suggesting working of the "Brass", "Eighteen Feet", "White" and "Bluers" seams is also provided on the Welsh Coal Mines website. The various drift mines were closed between 1962 and 1964 [9].

Operational years: circa 1840 - 1964

Seams worked:
Middle Coal Measures
White (Four Feet)
Eighteen Feet
Red Vein
Big (Nine Feet)
Peacock (Brass)

Lower Coal Measures
Bluers

Dulais Colliery

The Dulais Colliery (also referred to as Drym Colliery) was originally an anthracite slant (drift) mine built along the Neath and Brecon Railway; the colliery was located to the west of the Onllwyn Colliery. In 1905 a shaft was sunk to work the "Bluers" seam within the Lower Coal Measures. In 1930 the Dulais Colliery was working the "Peacock" seam and in 1935 the workings included the "New" seam. The drift mines associated with the "New" and "Bluers" seams were abandoned in 1917 and the "Nine Feet" seam was abandoned in 1926 (Note: no details regarding the initiation of workings within the "Nine Feet" seam are provided). The Dulais Colliery was closed prior to Nationalisation in 1947 [9].

Operational years: circa 1905 – circa 1947

Seams worked:
Middle Coal Measures
Nine Feet
Peacock (Brass)

Lower Coal Measures
Bluers
New (Gellideg)

Hendre Ladis Colliery – Ynyscedwyn Colliery

Note, neither of these collieries are shown on Figure 4. The Hendre Ladis Colliery was located approximately 1km to the west of the western site boundary and the Ynyscedwyn Colliery (which absorbed the Hendre Ladis) was located approximately 1.4km to the west of the western site boundary.

The Hendre Ladis Colliery, circa 1840, originally comprised a singular steeply inclined drift mine owned by the Ynyscedwyn Iron Company. No details of seams worked, whilst under the name "Hendre Ladis", are provided. Towards the end of the 19th century the colliery was absorbed by the Ynyscedwyn Colliery. The

'Ynyscedwyn Slant' (drift mine) worked the "Big" (also known as "Nine Feet") and "Peacock" seams. The Ynyscedwyn Colliery was closed by the National Coal Board in 1967/8 [9].

Operational years: circa 1840 - 1968

Seams worked: Middle Coal Measures
Big (Nine Feet)
Peacock (Brass)

Seven Sisters Colliery

The first of two shafts at the Seven Sisters Colliery was sunk in 1872. The two shafts were sunk to the "Nine Feet" seam which was encountered 183m below surface level. A list from 1923 shows that the "Four Feet" and "Brass" seams were being worked alongside the "Nine Feet" seam. The Seven Sisters Colliery was closed in 1963/4 [9].

Operational years: 1872 - 1964

Seams worked: Middle Coal Measures
Four Feet
Nine Feet
Brass

Glynllech Colliery – Cwm Tawe Colliery

Although no records of the Glynllech/Cwm Tawe Colliery are presented on the Welsh Coal Mines website, from review of historical mapping sources (Groundsure OS) the colliery is shown to be present to the north of the main site. The colliery is first shown on the 1914 mapping and is absent on the 1948 mapping suggesting a short period of operation.

Based on the location of the Glynllech Colliery and interpretation of published geological mapping, the Glynllech Colliery is anticipated to have worked the "Bluers", "Middle" and "Lower" seams; all of which sit within the South Wales Lower Coal Measures Formation.

9.3 Mine Entries

Based on review of the Coal Authority online viewer a total of 95No. mine entries have been identified within the site boundary. Sixty-four of the entries, both shafts and adits, are shown to be located within the main portion of the site. Thirty-one mine entry locations are shown to be present within the "washery" portion of the site [8]. The majority of the entry locations within the main portion of the site have been plotted on Figure 8 based on review of opencast completion plans and abandonment plans provided by Celtic Energy. However, the entry locations within the washery site were not shown on the source material provided by Celtic Energy.

In the north-western portion of the site a total of 24No. mine entries have been identified; seven of these entries are shown to be shafts (no depths provided) and the remaining seventeen are shown to be adits [8]. Based on the location, these

entries are anticipated to have been associated with the Abercrave and International Collieries; it should be noted that these entries have most likely been excavated out during the opencast mining activities associated with the Abercrave/Gwaunton opencast site (1973) and are therefore are unlikely to still be present (refer to Figure 9).

In the north-eastern portion of the site a total of 28No. mine entries are shown to have been present; nine of the entries have been identified as shafts and the remaining nineteen entries pertain to adits. Of the nine shafts identified, depths for three of the shafts were provided and range between 5.5m and 9.15m. Based on review of historical mapping, these entries are likely to have been associated with the Glynllech/Cwm Tawe Colliery. Two of the adits shown are located within the extent of the Abercrave/Gwaunton opencast site and have likely been excavated out. However, the majority are shown to be located in an area that has not been opencast and are therefore both the shafts and associated mine workings are still potentially present. No details on any 'treatment' (e.g. backfilling) of the entries in this location are provided on the Coal Authority online viewer.

A total of 12No. mine entries were identified to be present within the south of the site. Six of these entries pertained to shafts with known depths ranging between 3.6m and 4.6m and the remaining six entries were shown to be adits. These entries are likely to be associated with the Dulais Colliery and based on review of abandonment plans, the entries accessed the "Nine Feet" and "Brass" workings.

The presence of coal seams at shallow depth beneath the ground surface (both in the north and south of the site) means that they could be worked by bell pitting. Bell pitting as a method of extraction was often prevalent in areas where mineral deposits that are near-surface and shafts rarely extended beyond 10-12m in depth. From review of historical aerial photography from 1945, surface depressions have been identified that could be the result of bell pitting activities, see Figure 12 below.

Figure 12 Extract from 1945 aerial photography showing potential 'bell pitting'

A total of 31No. mine entries were identified to be present within the washery portion of the site. As the locations of these entries were not shown on any of the materials provided by Celtic Energy, the locations of these entries are not shown on Figure 8. The thirty-one entries within the zone include eight recorded shafts and twenty-three recorded adits. No depths were provided for the shafts identified on the Coal Authority viewer.

9.4 Underground Workings

Through review of abandonment plans provided by Celtic Energy (see Appendix F), the plan area extent and anticipated depth to workings for identified coal seams have been reviewed. It should be noted that the Coal Authority online viewer shows that the majority of the site is underlain by some form of underground workings. Abandonment plans held by the Coal Authority for these workings have not yet been acquired. (It is recommended that the available abandonment plans are acquired and reviewed as part of a more detailed desk study assessment).

Given the age and geographical location of the workings, 'partial extraction' methods are anticipated to have been used. As a result, residual voids associated with mining roadways and open stalls are likely to be present in the worked seams lying beneath the site.

Based on the '10t rule of thumb' (noted within CIRIA C758D) corresponding to 10 times the thickness (t) of an assumed unsupported high void/mining roadway [10]. If a 2m thick void is assumed – corresponding with the typical dimensions of a mining rowadway, the risk of subsidence associated with potential mining related voids is genrally considered to be sufficiently high to require mitigation or treatment when workings <20m below rockhead are anticipated to be present.

This bedrock cover value has been applied to the underground working plans reviewed to determine where the greatest risk of subsidence currently lies.

Table 4 – Underground workings summary table

ID	Description	Level (mAOD)	Depth to workings (m below current rock head)
A	Workings within the 'Nine Feet' seam anticipated to be associated with the Hendre Ladis/Ynyscedwyn Colliery.	Not provided	>>20 [1]
B	Workings within the 'Brass' seam anticipated to be associated with the Hendre Ladis/Ynyscedwyn Colliery.	Not provided	>>20 [1]
C	Workings within the 'Brass' seam anticipated to be associated with the Seven Sisters Colliery.	Not provided	>>20 [1]
D	Workings within the 'Nine Feet' seam anticipated to be associated with the Seven Sisters Colliery.	93.87	169

ID	Description	Level (mAOD)	Depth to workings (m below current rock head)
E	Workings within the 'Nine Feet' seam anticipated to be associated with the Dulais Colliery.	245.36 (Adit entry level)	<20 [2]
F	Workings within the 'Peacock' (Brass) seam known to be associated with the Dulais Colliery.	192.14 – 276.78	5 - 25
G	Unnamed adit believed to be associated with the Dulais Colliery. 'No Coal' notation on abandonment scan suggest it was a trial adit which was not progressed further.	243.84 (Adit entry level)	<20 [2]
H	Unnamed workings (assumed to be Bluers Seam within the Lower Coal Measures) anticipated to be associated with the Dulais Colliery.	143.43 – 176.78	87 - 97

Notes

1. Although depth to working and/or working levels were not provided on the plans used to identify these workings, based on the level provided on the plan to identify the level of working 'D', the depth to these workings is anticipated to be far greater than the 20m below rockhead range identified as highest risk within CIRIA C758D.
2. No in seam levels are provided. The depth to workings has been assumed to be less than 20m due to the limited plan area extent of the workings that spread from the adit entry points which are shown to be situated at surface level.

As highlighted in Table 4 above, underground workings at depths shallower than 20m below the current anticipated rock head are anticipated to be present. This particularly applies to workings 'E', 'F' and 'G' (refer to Figure 8).

It should be noted that cuttings (~10m) are currently proposed through the area that is anticipated to be underlain by workings 'E', 'F' and 'G'. These cuttings will lower the rock cover and in some instances underground workings may be encountered during excavation of the cuttings currently proposed (refer to Figure 11).

In these locations there is a risk of subsidence as a result of collapsed underground mine workings; in order to mitigate against the risk of subsidence, remedial actions such as grouting of voids may be required.

9.5 Open Cast Coal Mining

In addition to the extensive deep mine working continued beneath the site up until ~1966, the site has also been subject to extensive opencast coal mining activity from as early as 1946. From review of opencast completion plans (see Appendix G) and review of historical aerial photography, the various opencast sites have been identified and are shown on Figure 9.

A summary of the opencast sites identified is provided in Table 5 below; the operational years and an estimate of the maximum depth of excavation is also tabulated. The depth of excavation has been determined through review of opencast completion plans, where available, and current levels ascertained from online OS elevation data.

The depths of excavation provide indicative figures for the depth of fill material which is now present within the opencast sites that have been backfilled post completion of opencast activity. The backfill material is likely to comprise the non-coal bearing site won rock arisings which have been excavated during opencast working.

Table 5 – Opencast workings summary table

Name	Operational Years	Maximum depth of excavation
Onllwyn	1946 – 1949	~15m
Cefn Byrle [1, 2]	1952 – 1953	-
Abercrave / Gwaunton [1]	1963 – 1973	~40m
Onllwyn	1972 – 1982	~82m
Nant Helen	1986 – 1999	~130m
Nant Helen Extension	2002 - Present	~150m

Notes

1. Completion plans for the Cefn Byrle and Abercrave/Gwaunton opencast sites were not provided.
2. The existence of the Cefn Byrle opencast site has been determined through review of the 'History of Coal Mining' figure contained within the Nant Helen Extension Environmental Statement from 2011. Refer to Appendix H.

Refer to Figure 11 for an illustrative geological section which passes through the Onllwyn (1972-1982) and Nant Helen (1986-1999) opencast workings. The depths of the workings shown have been interpreted through review of the relevant opencast completion plans.

It should be noted that the extent of the Abercrave/Gwaunton opencast site shown on Figure 9 has been determined through review of figures provided within the Nant Helen Extension Environmental Statement (refer to Appendix H) rather than abandonment plans.

9.6 'Risk Zones'

A preliminary risk assessment has been undertaken in order to identify particular 'risk zones' along the proposed track route. The risk zones aim to highlight where the risk of subsidence as a result of shallow mine working collapse is highest. The

risk zoning has been primarily based on the areas that have are anticipated to have not been subject to opencast mining activity.

The risk zones are shown on Figures 8 and 9.

'Risk Zone A' is located in the south-eastern quarter of the main portion of the site. The zone covers the sections of proposed track from the western border of the second Onllwyn opencast site (1982) in the east to the eastern border of the Nant Helen opencast site (1999) centrally located within the site. There is a risk of subsidence in this zone due to the known presence of underground workings at shallow depth within the "Nine Feet" and "Brass" seams (see workings 'E', 'F' and 'G' on Figure 8); based on review of abandonment plans (provided by Celtic Energy), some of these workings are potentially as shallow as 5m below the current anticipated rock head and are therefore within the 20m below rockhead range which poses a crown-holing subsidence risk as determined from review of the CIRIA C758D guide. As highlighted in Section 9.4, as cuttings in the range of ~10m are proposed in this region of the site, the rock head cover is likely to be reduced and in some cases, workings are anticipated to be exposed by the proposed cuttings. In addition, potential 'bell pitting' activities have been identified within this zone from review of historical aerial photographs which further increases the risk of potential subsidence in this zone.

'Risk Zone B' is located in the north-eastern quarter of the main portion of the site. The zone covers the section of proposed track between the northern border of the second Onllwyn opencast site (1982) in the east to the eastern boundary of the Abercrave/Gwaunton opencast site (1973) located in the north of the site. There is a risk of subsidence in this zone due to the presence of numerous shaft and adit mine entries associated with the Glynllech/Cwm Tawe Colliery. Although a comprehensive set of abandonment plans for this region of the site have not yet been reviewed, there is the potential that shallow underground workings will be present in this area on account of the numerous shafts and adits; the depths of the shafts in this region (~5.5 – 9.15m) also indicate the potential presence of shallow workings within the 20m below rockhead range determined from review of the CIRIA C758D guide.

'Risk Zone C' is located in the south-western quarter of the main portion of the site. The zone covers the section of proposed track which runs from the southern border of the Nant Helen opencast site (1999) to the southern boundary of the Nant Helen Extension (2002 – present) located along the westernmost border of the site. There is a risk of subsidence in this zone due to the known presence of underground workings beneath the proposed track route. It should be noted that the risk of subsidence in this zone isn't considered to be as great as it is in zones 'A' and 'B' as the workings are anticipated to be much deeper than the 20m below rockhead range determined.

'Risk Zone D' covers the washery portion of the site. The zone has not been defined further as the exact locations of the shaft and adits identified to be present within the washery portion of the site could not be confirmed through review of opencast competition plans or abandonment plans provided by Celtic Energy. It is likely that Coal Authority data will have to be purchased in this region to cross

check the recorded locations of the mine entries shown on the Coal Authority online viewer.

It is recommended that a comprehensive set of abandonment plans are purchased and a ground investigation (including both intrusive and non-intrusive works) is scoped and undertaken to confirm the potential presence of shallow workings within the zones identified. If identified, remedial actions such as grouting of voids may be required in order to mitigate the risk of subsidence.

10 Sensitive Land Uses

Through review of information presented within the Groundsure EnviroInsight report, the following sensitive land uses have been identified within a 500m buffer of the site the site boundary. Refer to Figure 10 for the locations of the sensitive land uses identified.

Table 6 – Sensitive land uses

Sensitive Land Use	Name	Location
National Parks	Brecon Beacons	85m (NE)
Sites on Special Scientific Interest (SSSI)	Gorsllwyn, Onllwyn	19m (NE)
	Nant Llech	111m (N)
Ancient Woodland	Ancient semi natural woodland	On site
	Plantation on ancient woodland site	On site
Scheduled Ancient Monuments	"Tramroad at Ystradgunlais" *(a.k.a. Brecon Forest Tramroad – Claypons Extension)*	On site
	Bryn Llechwen ring cairn	90m (SW)

The border of the Brecon Beacons National Park is located approximately 85m to the NE of the northern site boundary.

The Gorsllwyn SSSI covers an area of approximately 40 hectares and comprises an upland mire located on a col between the Pyrddin and Dulais valleys. The peatlands within the mire are surrounded by an area of acidic grassland. The Gorsllwyn is deemed to be of interest as the mire landscape is rare with few other examples of this formation known in mid and south Wales.

The Nant Llech is a mountain stream that flows through a steep-sided valley of special interest on account of its rich variety of woodland species, cliff plant communities and Westphalian rock exposure. The site has been deemed critical for understanding the stratigraphy of the South Wales Coalfield due to the exposed sequence of over 120m of rock strata.

Through review of information presented within the Groundsure EnviroInsight report, multiple areas of 'ancient semi-natural woodland' and 'plantations on ancient woodland sites' have been identified. A small portion of the track route is shown to pass through an area of 'plantation on an ancient woodland site'. As set out in the National Planning Policy Framework (February 2019), *"development resulting in the loss or deterioration of irreplaceable habitats (such as ancient woodland…) should be refused, unless there are wholly exceptional reasons…"*. However, as the areas identified refer to areas of 'ancient semi-natural woodland' and 'plantations on ancient woodland sites', it is anticipated that these will have limited impact on the planning process for the future developments.

The 'Tramroad at Ystradgynlais' (also referred to as the Brecon Forest Tramroad – Claypon's Extension) is a Scheduled Ancient Monument and was built in the 1830s to link the Brecon Forest Tramroad and the Swansea Canal with the Drum Colliery.

The Bryn Llechwen ring cairn is also a Scheduled Ancient Monument and is located approximately 90m to the southwest of the western site boundary.

11 Preliminary Conceptual Site Model

The following section details a preliminary conceptual site model. The conceptual site model highlights the potential sources of contamination, identifies the potential receptors and sets out the potential pathways which would allow for a pollutant linkage to form.

11.1 Sources

The potential sources identified are highlighted in individual sub-sections below. It should be noted that the presence of potentially contaminated ground and groundwater beneath the site can only be confirmed through intrusive ground investigation and subsequent chemical analysis of geo-environmental samples gathered. The following identified contaminants for each identified source are purely indicative.

Made Ground

Based on review of the BGS online GeoIndex, review of borehole logs from previous ground investigations and from review historical mapping/photographs, made ground deposits are anticipated to be encountered beneath the majority of the proposed track route. The made ground materials are anticipated to comprise material used for infilling of the various opencast sites (refer to Figure 11). This material is likely to comprise gravels, cobbles and occasional boulders of mudstone, siltstone and sandstone (refer to photographs 3, 4, 5 and 6 in Appendix A).

No chemical testing on the made ground (fill) materials has been undertaken to date. This material is unlikely to be impacted by significant contamination; however, given the extensive usage of motorised plant in opencast mining

activities over the past 75 years there is the potential to encounter localised pockets of hydrocarbon (TPHs) contamination as a result of spillages.

As previously highlighted within this report, the site has been impacted by both sub-surface and surface coal mining activities. The Abercrave/Gwaunton opencast mine excavated the area previously occupied by the Abercrave, International and Gwaunclawdd Collieries. There is the potential that contaminants associated with coal mining activities could be encountered within the backfill in these locations. Contaminants arising from the coal mining infrastructure and activity in the area may be present; typical contaminants may include various metals, metalloids, sulphates, PAHs, TPHs and asbestos.

Rail/Tram Lines

The Neath and Brecon Railway (main and junction lines) have been identified to have run adjacent to the northern (junction line) and southern (main line) site boundaries through review of historical mapping and historical aerial photographs. In addition, three tramways (including the Brecon Forest Tramroad) have been identified to have crossed into the site through review of historical mapping and historical aerial photographs. Potential contaminants associated with rail/tram lines typically include various metals, TPHs, PCBs, PAHs, herbicides, ferrous residues, metal fines, ash, sulphates and asbestos.

Fuel Tanks

From review of site walkover photographs (see Photograph 7), a group of four large cylindrical tanks were identified to be present close to the site compound and offices centrally located within the site.

These tanks are likely to be fuel tanks or at the very least contain some form of hydrocarbon-based substance due to the nature of the flammable warning signs observed to be present. The tanks are above ground however, there is the potential that spillages and leakages may have occurred and as a result the soils and groundwater present in this location could potentially be impacted by hydrocarbon contamination.

Pollution Incidents

From review of the Groundsure EnviroInsight report, two pollution incidents have been recorded by the NRW within the site; an additional two pollution incidents were recorded <5m away from the site boundary taking the total to four. All four of the incidents were located within or within the direct vicinity of the washery portion of the site. The pollution incidents are detailed below.

In 2013 a pollution incident was recorded within the washery portion of the site (E: 283823, N: 210346). The pollutant was identified as ‘Coal’ and the impact to water was categorised as Category 2 (significant impact). No impact to land or air was recorded (both Category 4).

In 2001 a pollution incident was recorded within the washery portion of the site (E: 285452, N: 210250). The pollutant was identified as ‘Sewage Materials’ and the impact to water was categorised as Category 3 (minor impact). No impact to land or air was recorded (both Category 4).

In 2014 a pollution incident was recorded 1m to the south of the washery portion of the site (E: 285288, N: 210222). The pollutant was identified as 'Construction and Demolition Materials and Wastes' and the impact to both land and air was categorised as Category 3 (minor impact). The impact to water was not categorised.

In 2001 a pollution incident was recorded 4m to the northeast of the washery portion of the site (E: 285503, N: 210298). The pollutant was identified as 'Sewage Materials' and the impact to water was categorised as Category 3 (minor impact). No impact to land or air was recorded (both Category 4).

The pollution incidents presented above are anticipated to have had a localised impact to the soils and groundwater beneath the washery portion of the site. However, given the categorisation of these incidents the level of contamination is anticipated to be minor.

Landfills

No landfill sites have been identified within the site. From review of the Groundsure EnviroInsight report, the following historic landfills, see are located within 1km of the site boundary:

Table 7 – Historic Landfill sites – NRW Dataset

Name	Direction and distance from site	Type of Waste Accepted	Year of Closure
Moorside Villas	473m (NW)	Commercial Household	1974
Cowlbren	612m (N)	Unknown	Unknown

As neither of these landfills impact the site directly, the risk of encountering potential contamination associated with these two locations is considered to be negligible.

11.2 Receptors

The following potential receptors have been considered within the preliminary conceptual site model.

Human

- Construction workers/maintenance workers

  During the construction of the proposed cuttings and embankments, construction workers will be exposed to the soils and groundwater present beneath the site.

  Post construction, maintenance workers have the potential to be exposed to the soils and groundwater present beneath the site if works involving excavation activity is required.

- Site users

Post construction, site users are anticipated to include train drivers and maintenance workers carrying out works on the proposed test track. The train drivers are not considered to be vulnerable as they are highly unlikely to come into contact with soils and groundwater found beneath the site.

- Site neighbours

  Site neighbours includes people living in the various towns and villages that surround the site. This is particularly relevant to residents of Onllwyn which directly borders the site.

Environmental

- Surface Water

  Numerous surface water features have been identified to pass through the proposed site. These features are all small streams which are tributaries of the larger streams and rivers that surround the site.

- Groundwater

  The South Wales Coal Measures Formations that lie beneath the site are designated as Secondary (A) Aquifers. There are no known groundwater abstraction licenses within 500m of the site boundary however there may be unlicensed groundwater abstraction points surrounding the site.

11.3 Pathways – Pollutant Linkages

For a pollutant linkage to exist, an identified pathway has to be present to link a source to a receptor. The pathways identified have been split between human and environmental receptors and are presented below.

Human

- Ingestion of soils, soil dust and groundwater

  During construction, construction workers and site neighbours have the potential to come into contact with contaminated soils through ingestion of soils and soil dust.

  Post construction limited migration of soils and soil dust is anticipated to occur and therefore the likelihood of site neighbours to come into contact with potentially contaminated soils is negligible. However, maintenance workers have the potential to come into contract with contaminated soils through ingestion of soils and soil dust.

- Dermal exposure to soils, soil dust and groundwater

  During construction, construction workers are likely to experience dermal exposure to potentially contaminated soils, soil dust and groundwater. In addition, site neighbours also have the potential to experience dermal exposure to potentially contaminated soil dust that migrates from the site works.

  Post construction, maintenance workers are likely to experience dermal exposure to potentially contaminated soils, soil dust and groundwater.

- Inhalation of particulate matter and soil vapours

  During construction, construction workers and site neighbours have the potential to be impacted by contaminated soils through inhalation of particulate matter and soil vapours.

  Post construction, particulate matter and soil vapour is unlikely to migrate and therefore the risk of exposure to sit neighbours is considered to be negligible. However, there is a residual risk of exposure to maintenance workers.

Environmental

- Leaching and vertical/lateral migration

  The various excavation works currently proposed have the potential to introduce preferential flow paths for groundwater from the potentially contaminated superficial material (made ground) to the Secondary (A) Aquifer of the underlying solid geology.

- Surface run-off

  Breaking the ground, moving materials and formation of temporary storage stockpiles of made ground/fill may result in increased contaminant mobilisation due to increased exposure to rainfall. As this material has the potential to be contaminated, there is therefore the risk of surface run-off from the earthworks migrating migrate to the various surface water features that originate within the site.

- Direct discharge as a result of dewatering

  During the earthworks there may be a need to dewater the excavations. The removed water could be discharged to the wider site drainage or ground and, if contaminated, could potentially impact the receiving controlled water receptors.

12 Unexploded Ordnance

A preliminary risk assessment for the presence of buried unexploded ordnance (UXO) covering the site has been undertaken in accordance with CIRIA C681. The preliminary risk assessment has not been carried out by a UXO specialist and the assessment has been based on a desktop review of historical information regarding site location and previous site development.

12.1 The Site

The site is approximately 500 hectares in plan area. The site lies roughly ~20km to the northeast of Swansea and is bordered by the town of Ystradgynlais to the west and the village of Onllwyn to the east.

The site boundary roughly sits at around 250m AOD with the land rising towards the centre of the site. The majority of the central portion of the site is at around 295m AOD with localised artificially raised areas of land reaching 335m AOD. The “washery” portion of the site sits lower than the main portion of the site at roughly 230m AOD.

Based on review of current online aerial photography, the main portion of the site is shown to be a moorland type area with significant evidence of opencast mining activity. The majority of the active opencast evidence is present to the west of the main portion of the site although areas of land that appear to have been backfilled opencast sites are present in the east of the site. The centre of the main portion is shown to contain artificially raised "overburden storage area/layer-cake" spoil heaps. These areas of land are significantly raised compared to the surrounding area with the largest

The "washery" portion of the site is shown to contain a varied array of coal processing infrastructure with a limited network of rail lines running along an east to west alignment towards the north of the site. The land surrounding the coal processing infrastructure appears to be raised industrial scrubland with minimal vegetation cover.

12.2 Geology

Based on review of published geological sources, the site is shown to have a limited and discontinuous cover of superficial deposits. Glacial till deposits, covering a minimal plan area, are shown to be present along the southern and western boundaries of the site. Glacial till material tends to comprise a heterogenous mixture of predominantly clay sized material, with sand, gravel and larger cobble and boulder sized inclusions. In addition, a small peat deposit is shown to be present within the central portion of the site.

12.3 Proposed Works

The proposed earthworks include comprehensive cut and fill activities to form a range of embankments and cuttings; the embankments and cuttings are required to form the base for a rail test track facility. Based on current ground levels it is anticipated that cuttings of up to ~30m deep and embankments of up to ~40m high will likely be required. The majority of the cuttings proposed are through backfilled opencast sites with a few sections of rock cut anticipated.

12.4 Site History

Based on review of aerial photography from 1945, the main portion of the site is shown to be free from any major development and appears to comprise moorland with numerous small fluvial valleys originating from the centre of the site. Significant coal mining activity is shown along the northern boundary (Abercrave, Gwaun Clawdd and Ynyscedwyn Collieries) and the southern boundary (Onllwyn, Dulais and Seven Sisters Collieries). A linear alignment of minor cuttings and embankments is shown to cross along the southern boundary of the site. From review of historical mapping this alignment is labelled as an 'Old Tramway'; the tramway is labelled 'Old' on the earliest available historical mapping from 1876 which suggests that the tramway had long been disused at the time of WWII. The "washery" portion of the site contains the Onllwyn Washery with multiple rail lines and stockpiles present.

Post WWII, the site has undergone significant opencast mining activities. The progression of opencast activity has progressed from east to west with the earliest opencast site, Onllwyn (1949), being located beneath the eastern boundary of the main portion of the site and the most recent opencast site, Nant Helen Extension (2002 - present), being located beneath the western boundary of the site. The "washery" portion of the site appears to have remained relatively unchanged since WWII with a slight reduction coal processing infrastructure noted; a raised portion of the industrial scrubland to the north of the Onllywn Washery has possibly been formed from the stockpiles noted from the 1945 aerial photography.

12.5 Evidence of previous military land-use

The site located has historically been used for coal mining with no evidence of military use in the direct vicinity of the site. From a review of potential military sites collated on the Coflein website, no major military targets have been identified within a 10km radius of the site [18].

Swansea is located approximately 20km to the southwest of the site. Swansea was a target of major Luftwaffe bombing raids during WWII and was the most heavily bombed location in South Wales. However, given the distance, it is unlikely that the site will have been impacted by Luftwaffe bombing raids targeted at Swansea.

12.6 Potential for aerially delivered ordnance

The Zetica regional unexploded bomb risk map for Glamorgan shows that the site is located within a low bomb risk map. In addition to the regional unexploded bomb risk map, a bespoke unexploded bomb risk map for the site has been freely downloaded from the Zetica website, see Figure 13 below.

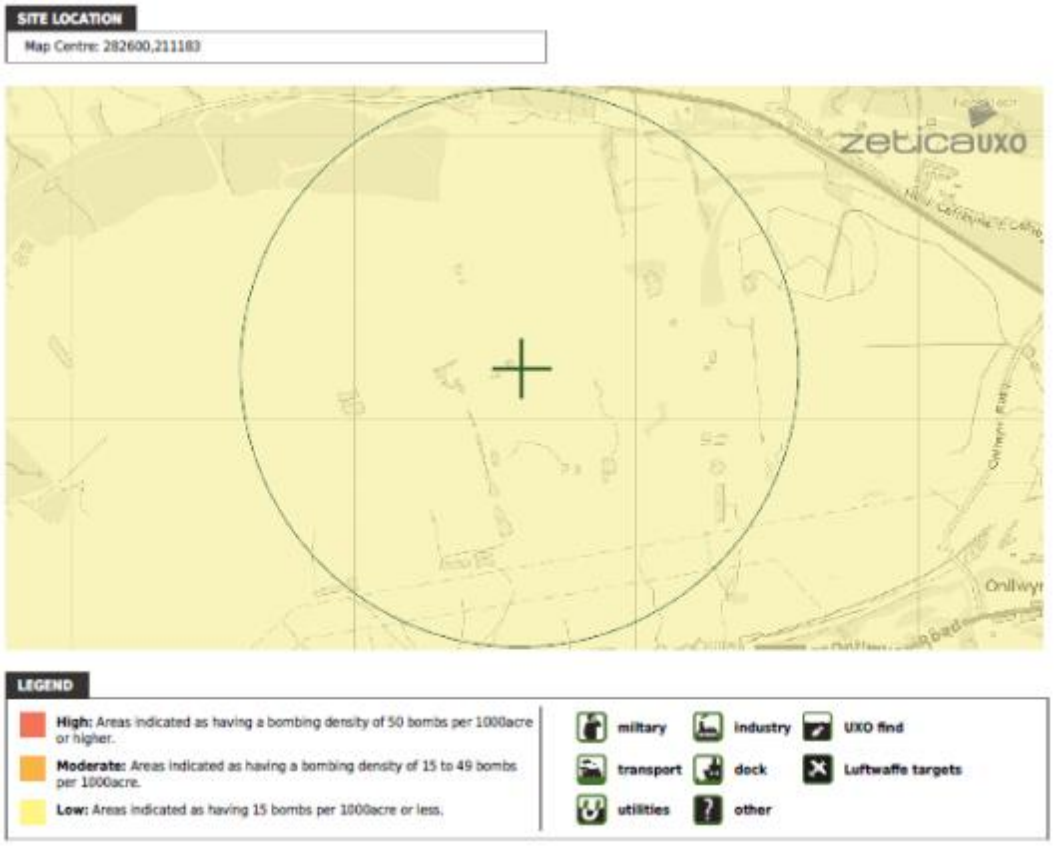

Figure 13 Zetica Unexploded Bomb Risk Map

As shown above, the site sits within a low risk area. A low risk area is defined as an *"area indicated as having 15 bombs per 1000 acres or less"*. As set out by Zetica, a low risk area suggests that there is no greater probability of encountering UXO than anywhere else in the UK. Therefore, the potential for aerially delivered ordnance is low.

12.7 Consideration of mitigating factors

The predominantly firm nature of the glacial till superficial geology and reported lack of superficial geology in some areas of the site, means that had any aerially delivered ordnance been dropped it is highly likely to have detonated upon impact. Also, given the general absence of soft superficial deposits, other than areas of peat in the central areas of the site it is likely that any UXO would have been discovered on the ground surface and dealt with.

No previous military land use was identified within a 10km radius of the site. The collieries and rail infrastructure present surrounding the site at the time of WWII do represent a potential target for WWII Luftwaffe bombing raids. However, given the localised nature of Luftwaffe bombing raids in Wales (primarily concentrated on Swansea, Cardiff and Milford Haven), it is unlikely that the collieries surrounding the site would have been targeted.

The extensive nature of post WWII development to the site, primarily regarding opencast mining activity, further reduces the risk of UXO encounter. This is particularly relevant when considering that the majority of cuttings currently

proposed pass through areas of previously backfilled opencast sites. The remaining cuttings are proposed through areas where superficial deposits are anticipated to be minimal. The areas of peat which were historically present will generally have been worked out during the open-casting operations that historically took place on the site.

12.8 Conclusions and recommendations

Based on the preliminary UXO risk assessment detailed above, the risk of UXO encounter beneath the site is considered negligible. As a result, a detailed UXO risk assessment is not deemed to be required.

13 Preliminary Engineering Assessment

From the information available, a preliminary geotechnical and geo-environmental assessment has been undertaken to identify the potential constraints at the site.

The engineering assessment has considered issues regarding settlement, the earthworks proposed, the potential for material re-use, issues regarding groundwater and potential foundation options for the structures proposed.

13.1 Settlement

A literature review regarding the estimation of settlement at the site was undertaken using the following documents:

- BRE Report – Building on Fill: Geotechnical Aspects (3rd edition)[13];
- BRE Information Paper IP 5/97 – Building on Fill: Collapse Compression on Inundation [14];
- BRE Information Paper IP 15/85[15];
- British Coal Opencast: State of the Art Review of The Compaction of Opencast Backfill. Report No. 90CPC/GEO/095 dated March 1997 by Scott Wilson Kirkpatrick (3 vols) [16];
- Building on uncompacted dumps in the Rhenish brown coal area of the Federal Republic of Germany. Lange S. 1986 [17].

For opencast backfills such as the ones on site, the mechanisms of ground movement include:

- long term creep settlement – most settlement occurs;
- settlement due to inundation;
- heave movements associated with inundation and/or stress relief;
- movements as a result of load imposition.

The primary factor affecting magnitude of these settlements is degree of compaction. Uncompacted fills (e.g. by end tipping in thick layers) show the most settlement. Other controlling factors which need to be considered include backfill properties (e.g. particle size and shape, grading, particle strength hydraulic properties), shape, depth and extent of excavation, location of spoil mounds, haulage roads and hydrogeological effects.

13.1.1 Creep settlement

Most settlement occurs during and soon after backfilling. Assuming that the majority of backfill is granular; major settlements are likely to have occurred almost immediately upon backfilling.

Further movement then occurs gradually and is known as long term creep settlement, the rate of movement decaying linearly when plotted on a log-time scale. The slope of the graph of movement versus log time is known as the logarithmic creep compression parameter, α.

For opencast backfills containing sandstone/mudstone rockfill, conservatively assumed to have been non-engineered (i.e. has had no systematic compaction), this parameter typically lies in the range 0.9% to 1.5% [13]. This range of α values have been used to determine the likely rate of creep settlement occurring in the areas of opencast that have since been backfilled.

In addition, following the BRE building on fill guidance [13], a less conservative logarithmic creep compression parameter value of 0.34% for the Nant Helen opencast site has been calculated for engineered (i.e. heavy vibrating roller compaction) sandstone/mudstone rockfill. The backfill has been assumed to be dry ($\therefore \sigma_v' = \sigma_v$).

Sandstone/mudstone rockfill	Heavy vibrating roller	0.13 σ'_v
Sandstone/mudstone rockfill	No systematic compaction	0.9–1.5

The creep settlement has been estimated for various values of a logarithmic creep compression parameter (α) using the equation below.

$$\alpha = \Delta s/[H \log (t_2/t_1)]$$

Where, 'Δs' refers to the settlement of an embankment of height 'H' between times 't_2' and 't_1'.

A general assessment of the magnitude and timescale of future movements, considered sufficient to establish the feasibility of development plans, has been made using desk study information on the geometry/depth, age, type and hydrogeological regime of the backfill, together with settlement monitoring records.

Refer to Figure 14 for the estimated rate of creep settlement for different α values for the Nant Helen opencast site. The Nant Helen opencast site was chosen to illustrate the potential rates of creep settlement as the site represents the deepest of the backfilled sites (~130m).

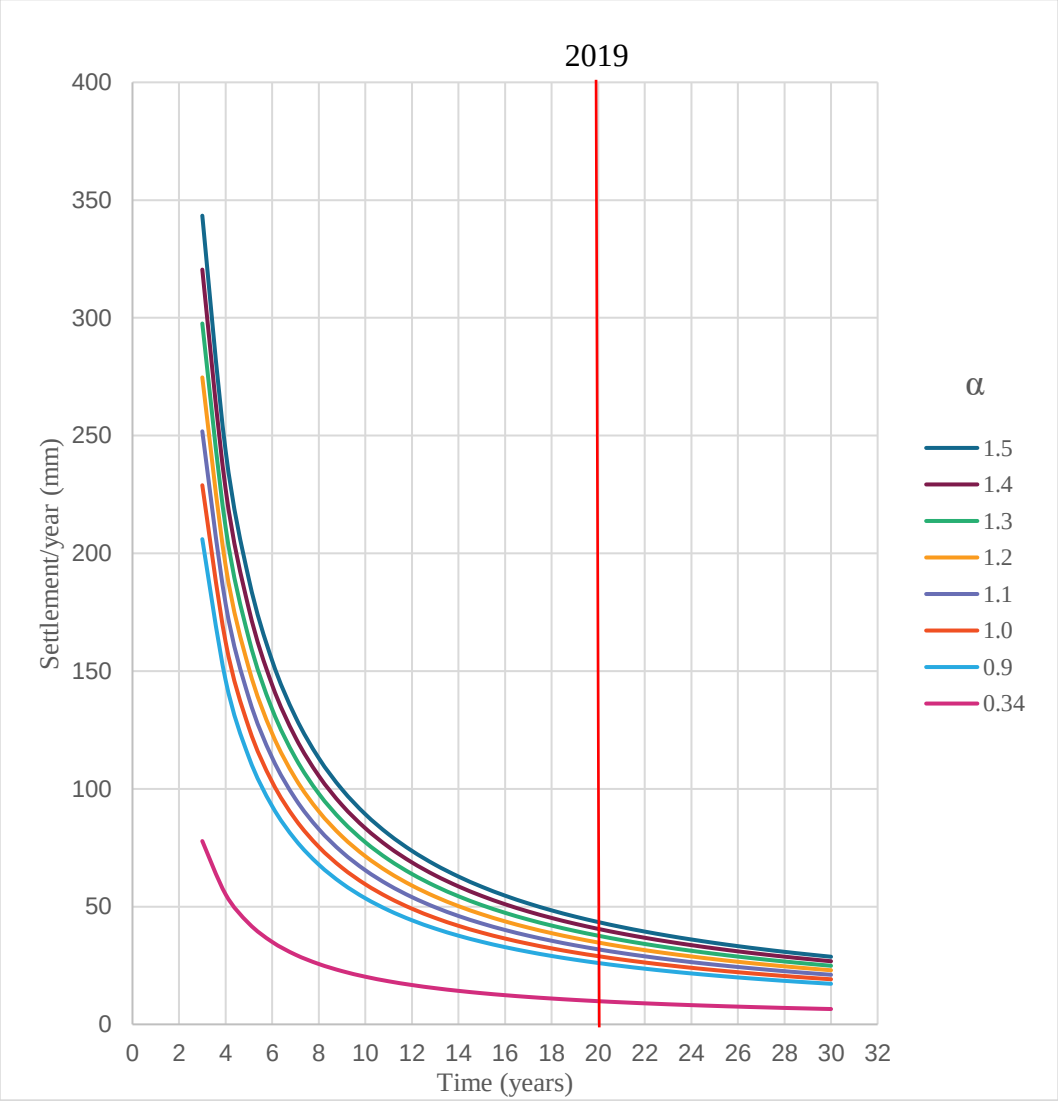

Figure 14 Creep settlement rate for different α values (Nant Helen 1999)

For all alpha values, based on this assessment the current creep settlement rate is anticipated to be in the range of 10-50mm per year.

As highlighted in Figure 14 above, the risk of creep settlement is considered to be greatest within the areas that have been recently been backfilled. This risk particularly pertains to the Nant Helen Extension site beneath the western boundary of the site where the opencast void is yet to be backfilled.

The detailed design of remediation works and foundation solutions will need to consider the effects of specific features such as spoil mounds, sloping sides of excavation, potential “hard spots” at edge of excavation and hydrological/ hydraulic features in the proposed development.

A suitable scope of ground investigation works will need to be undertaken to provide information on the detailed geotechnical properties of the backfill.

13.1.2 Inundation settlement of fill following the rebound of the groundwater level

Inundation settlement occurs relatively rapidly following inundation of susceptible fill materials by groundwater or surface water. Sensitivity to inundation settlement depends on air voids content prior to saturation. Inundation settlement is negligible when air voids are less than 5% and of small magnitude when air voids are less than 10%. On the other hand, linear strains of the order of 3% to 5% have been measured in many loose fills [14].

This is likely to affect the western part of the site mainly, where dewatering activities are currently being undertaken to allow for the excavations within the Nant Helen Extension opencast site. Once dewatering is ceased, the groundwater levels in this region will rebound to a certain level. Given the general lack in groundwater information for the site, this rebound will have to be monitored to determine the level to which groundwater will rise post completion of opencast working. This monitoring should be undertaken site wide; initially to gain an appreciation for the groundwater level currently beneath the site and to then measure the change in groundwater level, if any, that occurs once the dewatering measures are stopped.

As inundation settlement can be mitigated somewhat through control of air voids within the fill material, opportunities to minimise this risk during the filling of the current opencast voids located to the west of the site should be fully explored.

13.1.3 Potential differential

There is the potential for differential settlements to occur along the proposed track route. This is due to the fact that the areas of backfill will settle whereas the areas that have not been subject to opencast working are unlikely to settle.

There is likely to be a degree of differential settlement within the areas of backfill themselves. This is due to the fact that total settlement is dependent on the thickness of fill; as the thickness is not constant, the areas with greater thicknesses of fill will settle more than those with a shallower thickness.

In order to mitigate against differential settlements at the surface, improvement of near surface materials could be considered. It should be noted however that this would not eliminate total settlements. Improvement of near surface materials could be achieved by:

1. Excavating and recompacting
2. High Energy Impact Compactions (HEIC) (likely to improve the upper ~3m)
3. Dynamic Compaction (likely to improve the upper ~10m)
4. Surcharge
5. Grouting

Alternatively, a rigid base to track bed could be proposed. This would mitigate against the risk of minor differential settlements but would likely require comprehensive piled foundations, which would not be a feasible solution for the deeper areas of fill.

As settlement is likely to occur at the highest rate within the areas that have most recently been backfilled, altering the proposed alignment to avoid the most recent areas of opencast mining would minimise the risk of differential settlement. Ideally the alignment should be altered to avoid the areas of recently backfilled material where possible.

13.1.4 Heave

Elastic heave movements can occur when cuttings are formed through fill material or on removal of surcharge mounds. Heave can also result from the swelling of near surface deposits caused by water ingress and seasonal moisture content changes.

The risk of heave should be considered in any areas where removal of material from the large overburden storage areas is proposed or any areas where extensive cuttings are proposed.

13.2 Proposed Earthworks

The extent and size of cuttings and embankments required is dependent on the proposed track level. The slope angles of the cuttings and embankments are dependent on material. Based on the anticipated nature of the material used for the embankments and cuttings, and the anticipated groundwater regime across the site, the following slope gradients have been estimated to ensure stability with adequate factors of safety:

- Embankments – 1:3
- Cuttings (coal measures) – 1:1
- Cutting (backfill) – 1:2.5

It should be noted that the slope angles for the cuttings and embankments proposed here are indicative only, and should be verified following ground investigation on the basis of stratigraphy, material and mass properties and the results of groundwater monitoring.

13.2.1 Areas at Risk of Shallow Mine Workings

The risk zones identified in Section 9 of this report highlight the areas where opencast working has not been undertaken and shallow mine workings may be present. Within such areas of shallow mine workings, the development proposals may be susceptible to impacts from potential subsidence events. Excavation of cuttings would reduce the thickness of cover over the workings, increasing the risk that ‘crown hole’ collapse could propagate to the surface and affect the proposed development.

For example, in 'Risk Zone A' workings <20m below the existing rockhead are anticipated. Workings within this range present the highest risk of subsidence as a result of roadway collapse. Given the age of the workings, roadway collapse may occur due to the degradation of supports present at any time.

The cuttings are likely to reduce the depth to workings, and in some cases expose wokrings, due to the removal of material. This is likely to bring more workings within the 20m (particularly in 'Risk Zone A') range which has been highlighted as highest risk.

Engineering measures are likely to be required to effectively lower the risk of shallow working related subsidence within risk zones. This could include bulk infilling of mining voids such as grouting of voids (or use of gravel where drainage pathways need to be maintained), or use of high strength geogrids to temporarily or permanently span potential subsidence features.

13.3 Potential for Material Re-use

An assessment of the suitability of material re-use in the construction of the numerous embankments proposed will be necessary as part of the scope of ground investigation works. From review of the site walkover photographs, much of the made ground fill material anticipated to be encountered within the backfilled opencast sites is likely to comprise gravels, cobbles and occasional boulders of mudstone, siltstone and sandstone. This material is expected to be predominantly granular, predominantly comprising the non-coal bearing material that has been excavated during opencast working.

This material is also likely to be representative of the material that would be generated during the excavation of the cuttings required through areas of previously unworked Coal Measures Formations.

From a geotechnical perspective, this material is likely to be suitable for re-use subject to processing to reduce the maximum particle size and achieve a suitable grading, and removal of any coal that may still be present.

The glacial till natural superficial material is also likely to be geotechnically suitable for re-use in the formation of the embankments required.

The deposits of peat are likely to be unsuitable for reuse as a fill material. Furthermore, if present, it is likely that any peat present in at grade sections or beneath the proposed embankments will have to be excavated and removed from the areas or treated prior to construction.

The geotechnical suitability for material re-use, can only be confirmed through geotechnical sampling and subsequent testing of the materials present within the opencast areas that have been backfilled.

From a geo-environmental perspective, the potential contaminative nature of made ground fill material must be assessed in order to determine the suitability for re-use. Human health and controlled waters risk assessments will be required to determine the geo-environmental suitability for re-use.

13.4 Groundwater

As discussed in Section 13.1.2, further understanding of groundwater levels beneath the site is required to inform assessment of inundation settlements.

Groundwater has the potential to impact the settlement in the areas of backfill and affect the proposed cuttings. It is recommended that a ground investigation is undertaken to ascertain the groundwater level beneath the site.

13.5 Foundation Options – Structures proposed

In addition to the track loops, it is envisaged that a platform environment, facilities for rail storage, train decommissioning areas and other testing facilities may also be included as part of the developed works.

The proposals are likely to comprise the construction of numerous structures of various sizes. These structures may be located within the main area of the site and also within the washery portion of the site.

In the main portion of the site outside any areas of historical opencast activity it may be feasible to found buildings on pad or raft foundations with the glacial till or on top of the relatively shallow bedrock.

The layout of the development should consider the risks presented by ongoing settlement of the backfill.

It may be feasible to found buildings within the areas of previous opencast activity on pad and raft foundations. This is subject to future ground investigation of the ground conditions and careful consideration of the potential magnitude of settlements; in-particular, the differential settlement that may occur within the backfilled opencast workings. Understanding the location of the historical workings will be important for assessment of potential variations in settlement across the site.

Regardless of ongoing settlements, any heavily loaded buildings in these areas may require the use of piled foundations or some form of ground improvement to limit potential settlements under loading to acceptable limits.

As highlighted within the ground conditions section of this report, artificial material (made ground) overlying natural superficial material (predominantly glacial till, potential for peat) is likely to be encountered within the washery portion of the site. The depth to weathered rockhead is anticipated to vary, up to depths of 7.0m bgl based on the logs reviewed. The descriptions from boreholes progressed within the washery portion of the site suggest that the bedrock is comprised of mudstones and siltstones which are slightly to moderately weathered and are moderately weak to strong.

Based on the anticipated ground conditions in the washery portion of the site, it is possible that piled foundations may be required; however, it should be noted that the foundation type is highly dependent on the loading of the structures proposed. For example, smaller structures with lower loading may be able to be founded on pad or raft foundations.

The subsidence risks associated with shallow mine workings will need to be considered as part of the foundation selection regardless of the foundation type selected some form of mine workings treatment or mitigation is likely to be required within identified risk zones.

The extent of ground treatment and foundation selection will need to be reviewed once more detailed assessment of mining risks and ground investigations have been undertaken.

It is recommended that the development masterplan is developed to minimise risks associated with potential total and differential settlement associated with former backfilled opencast areas, potential mining related subsidence associated with shallow underground mine workings.

14 Geotechnical Risk Register

The Geotechnical Risk Register has been established and will be updated as the scheme progresses and when constraints or opportunities are identified.

Table 8 – Geotechnical Risk Register

Hazard		Consequence	Mitigation Measures
1.	Differential settlement between areas of undisturbed ground and infilled ground.	Potential for structural damage and serviceability issues with the test track and associated structures and infrastructure.	Ground investigation and testing to better understand the make-up of infill – determine geotechnical design parameters for undisturbed and infilled ground. Monitor existing ground movements in order to test theoretical information regarding ongoing ground movements in areas of backfilled opencast workings. Monitor groundwater and undertake detailed hydrogeological risk assessment to understand potential changes in the hydrogeology and potential for future inundation settlement.
2.	Continuing total and differential settlement of infilled areas (associated with backfilled former opencast works).		Develop masterplan and detailed design taking account of areas of higher risk and avoiding these where possible.
3.	Inundation settlement of the infilled areas due to groundwater rebound once dewatering stopped as a result of changes in groundwater regime due to installation of new drainage/soakaways.		Ensure that foundation solutions for structures make due allowance of potential ground movements during design life.
4.	Inundation settlement of the infilled areas due to creation of new drainage paths e.g. installation of drainage across the site.		Design for ground movements e.g. ensure flexible joints in any drainage pipes, incorporate suitable gradients for drainage runs to minimise risks of drainage backing up in the event of differential ground movements occurring.
5.	Potential for significant ground heave in areas of deep cuttings.		Design for regular maintenance, e.g. tamping of track as part of overall development strategy.
6.	Shallow underground coal workings and associated mine entries, including shafts and adits have been identified to be present beneath sections of the proposed cuttings and embankments	Potential subsidence as a result of underground working of mine entry collapse leading to failure of track and potential train derailment in the permanent case.	Comprehensive review of all available mine abandonment plans pertaining to workings that are closest to the surface of rockhead (~20m below rockhead).

Hazard		Consequence	Mitigation Measures
		Risk of encountering underground workings or intact coal seams in the areas of proposed cut. This will need to be considered both in terms of developing safe construction methodologies and permanent works to ensure stability and safety of the final earthwork.	Undertake ground investigation comprising a mixture of intrusive and non-intrusive (e.g. non-intrusive gravity surveys) works in order to locate potential shallow mine workings. If shallow mine workings are identified, mitigatory measures such as grouting of voids may be required to negate the risk of subsidence beneath the proposed track route.
6.	Oversteep slope angles in proposed cuttings and earthworks	Failure of earthworks: Cutting – material on the tracks causing derailment Embankment – failure of embankment and track causing derailment.	Ground investigation – design geotechnical parameters and slope stability calculations.
7.	Encountering potentially hazardous material from historical and current mining activities within the infilled areas.	Risk of encountering made ground which is potentially hazardous to human health and controlled waters.	Undertake ground investigation and sub-sequent sampling on geo-environmental samples gathered to determine the type and degree of contamination if present.
8.	Potential for instability within rock cuttings or beneath embankments as a result of failure along discontinuities and weak bedding layers within the coal measures (such as coal seat earths).	Large scale instability of rock cuttings.	Design appropriate cutting slopes and if necessary incorporate stabilisation measures such as rock anchors.
9.	Pyrite is known to be present within the Coal Measures bedrock.	Pyrite containing bedrock can present aggressive conditions to concrete foundations.	Undertake ground investigation and subsequent aggressivity testing of samples gathered to determine the potential threat to concrete foundations.

15 Conclusions and Recommendations for Further Work

Through undertaking this desk-based study of the 'Land at Nant Helen and Onllwyn Coal Washery' site the following conclusions have been made.

As identified through review of published geological sources, whilst the majority of the site is shown to have limited natural superficial soil cover, localised areas of glacial till and peat are likely to be encountered.

The superficial material is underlain by the South Wales Lower and Middle Coal Measures Formation. A significant number of coal outcrops are present within the site boundary. A number of approximately North-South trending faults cross the site. The solid geology beneath the site is likely to be complicated on account of the various anticline and syncline features which have been identified through review of published geological mapping sources.

The site has been significantly impacted by both opencast and underground coal mining activity. Large areas of the site have been subject to opencast mining activity. Most of the former opencast areas have been backfilled. The depth of backfill pertaining to each has been estimated from review of opencast completion plans with ~130m of backfill material likely to be present within the original Nant Helen opencast site. The Nant Helen Extension opencast site has reached depths of up to 150m, however this site is yet to be backfilled. The backfill material is likely to be settling at variable rates due to the varied depths of deposition and the assumed 'non-engineered' backfilling methods.

From review of limited abandonment plans provided by Celtic Energy, localised areas of shallow underground mine workings are present; in places these workings are anticipated to be within 20m of rock head. Based on review of the coal mining information provided on the site, four risk zones (A through D) have been identified. These risk zones cover the sections of proposed track where underground workings are likely to be present at less than 20m depth below rockhead; essentially these zones pertain to the sections of the track that are shown to lie on land that has not been opencast previously.

Numerous watercourses are shown to flow through and originate from certain sections of the main portion of the site. These watercourses are predominantly small in nature and are tributaries to the River Tawe, Dulais River and River Pryddin that surround the site. Multiple pond features have been identified within the site; these features are a mixture of natural and man-made features. The majority of the site is not at risk of flooding with only a very small section at the easternmost corner of the washery portion of the site being at risk.

The groundwater level beneath the site is relatively unknown as the Nant Helen Geotechnical borehole logs reviewed provided no information regarding the groundwater level. However, from review of the Nant Helen Extension Environmental Statement from 2011, the groundwater level in the west of the site was previously recorded to sit at around 120m AOD; this suggests that

groundwater is at around 170m below ground level in this location. Due to the extensive nature of the underground workings anticipated beneath the site, it is likely that the site is underdrained by these workings particularly by adit mine entries discharging to the River Tawe to the north of the site. Shallow groundwater strikes were recorded in the borehole scans reviewed pertaining to boreholes within the washery portion of the site.

The preliminary conceptual site model has identified the potential for certain pollutant linkages to be formed during future site works. These linkages pertain to the potentially contaminated nature of materials that will be encountered beneath the site. The level of contamination is yet to be assessed however a number of potential sources, primarily based on the site's industrial past, have been identified.

Following a preliminary unexploded ordnance (UXO) risk assessment, the risk of encountering UXO beneath the site is considered to be negligible. As a result, a detailed UXO risk assessment is not likely to be required.

15.1 Settlement Monitoring

In order to better understand the potential settlements that are occurring within the areas of opencast workings which have since been backfilled, settlement monitoring using permanent ground markers installed at surface is recommended. The monitoring information would be useful and would be supplemented with intrusive ground investigation as the project progresses.

Settlement monitoring will be useful to ascertain the current rate of ongoing creep settlement within the areas of backfill and potentially monitor settlements which occur post-inundation once dewatering activity associated with the current opencast workings is ceased. Groundwater level monitoring will be required to determine the rebound of the groundwater level that occurs once dewatering measures are stopped. The scope of settlement monitoring should be developed to allow an assessment of potential total and differential creep movements over the design life of the development to be better understood and provide greater certainty regarding the potential impacts of this; the monitored settlements can then be compared with the theoretical 'creep movements' determined as part of this study.

15.2 Detailed Mine Workings Study

Given the extensive nature of underground working shown to be present beneath the site it is recommended that an additional study is undertaken to provide a comprehensive review of the underground workings that are likely to be present beneath the site.

Through consultation with the Coal Authority, a total of 42No. abandonment plans have been identified in relation to the shallow workings beneath the site. It is recommended that these plans are purchased at a later date and a comprehensive review of the shallow workings recorded beneath the site is undertaken. This review would allow for the areas that are potentially at risk of subsidence to be

much better understood and will better inform the scope of ground investigation ultimately proposed.

15.3 Ground Investigation

It is recommended that ground investigations are undertaken. This ground investigation is likely to require both intrusive and non-intrusive works in order to ascertain information on the site that is currently lacking. Ground investigation is required to;

- Confirm the ground and groundwater conditions beneath the site, including the different areas of former opencast workings - primarily focusing on the current proposed track route. In-situ testing and geotechnical sampling with subsequent testing will be required to determine the geotechnical properties of the materials encountered which will then feed into the design of the cuttings and embankments proposed;
- Investigate the composition and in-situ properties of the fill material within the backfilled opencast sites which are located beneath the proposed track route. This is required to be able to better understand the potential settlements that are likely to arise as a result of long term creep settlement. Investigation of the groundwater level within these areas and interpretation of the change in groundwater level, post completion of all opencast activity, will help inform the likely inundation settlements that could occur as a result;
- Identify the potential presence and significance of contaminated ground and groundwater beneath the site. Geo-environmental testing with subsequent chemical analyses will be required to allow suitable risk assessments to be undertaken both for the discharge of planning conditions and for the design and specification of any necessary site remediation works required;
- Determine the depth to underground workings, if present, beneath the proposed track route through intrusive investigation (probing) and potentially also geophysical methods (e.g. Gravity surveys or magnetic surveys to locate shaft locations). If identified information will need to be suitable to allow for the design of treatment measures such as grouting of mining related voids. The information should also be sufficient to allow an assessment to be made of the potential impacts of mine-workings treatment on the hydrogeological regime.

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Figures

The following figures have been included in the main body of the report.

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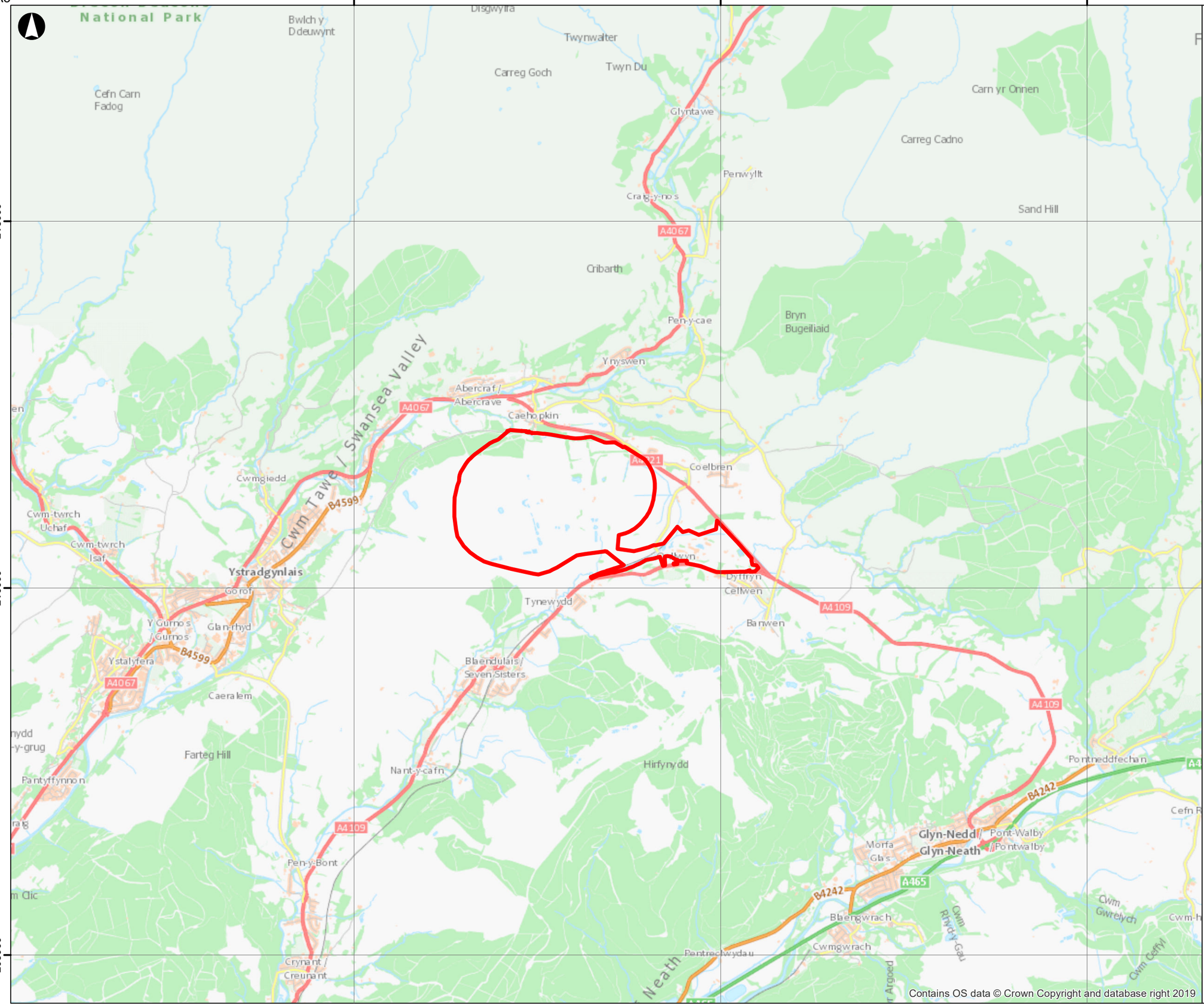

Legend

Site Boundary

10/12/2019 11:19:22

Coordinate System: British National Grid

Metres

0 500 1,000 2,000

Rev	Date	By	Chkd	Appd
P1	10-12-2019	JC	TW	DR

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Project Title
Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Site Location Plan

Scale at A3
1:50,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

Rev
P1

Name
Figure 1

J:\264000\264904-00\4 Internal Project Data\4-80 GIS\4-84 Map Documents\GEO_Geotechnics\DS\Figure 1_Site Location Plan.mxd

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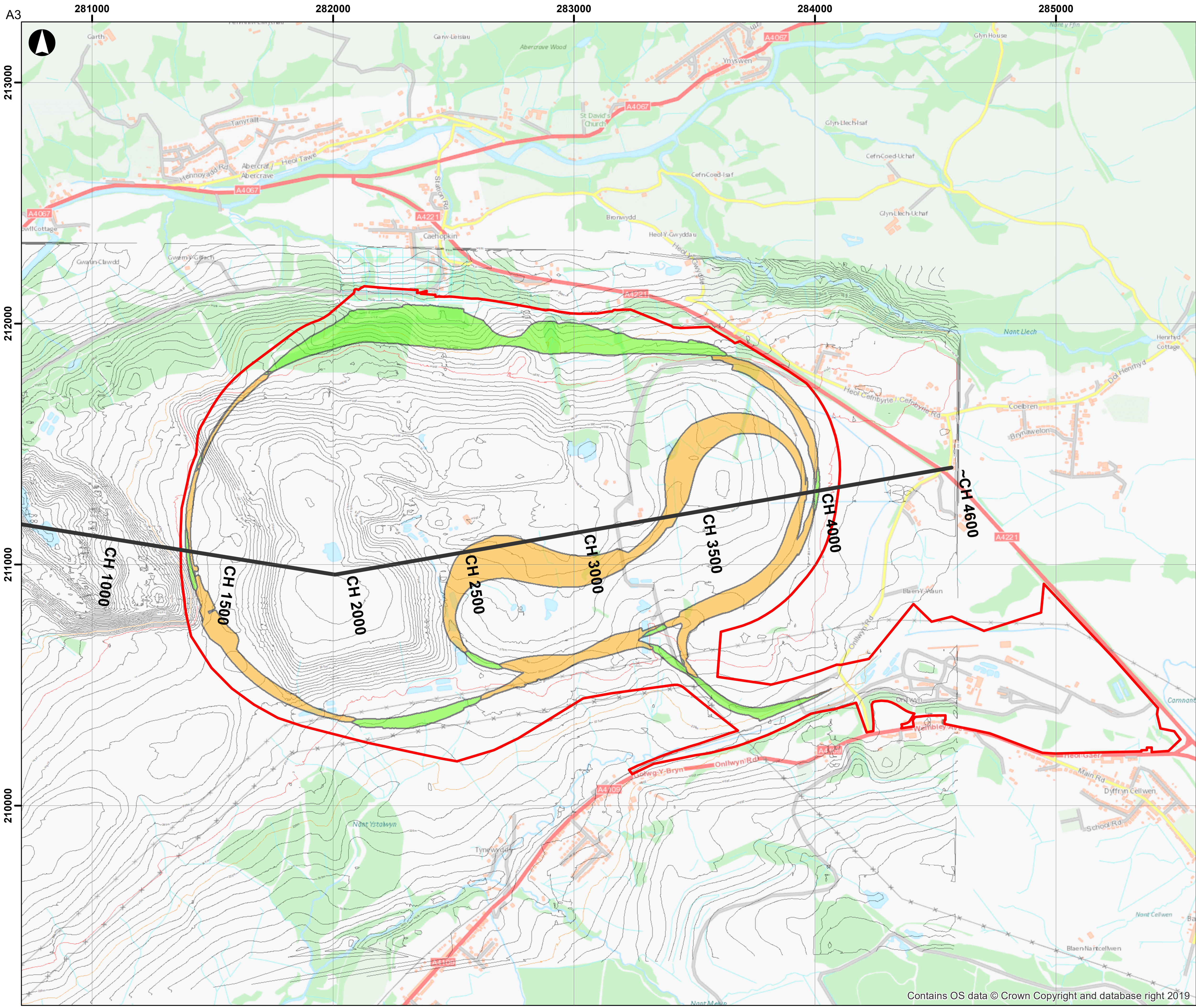

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12/12/2019 16:41:44

Legend

Site Boundary

Indicative Extent of Proposed Earthworks

Cuttings

Embankments

Figure 11 Section Line

Coordinate System: British National Grid

Metres
0 400 800

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Drawing Title
Outline Scheme Earthworks Proposals

Scale at A3
1:15,000

Role
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Suitability
For Information

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264904	**P1**

Name
Figure 2

A3

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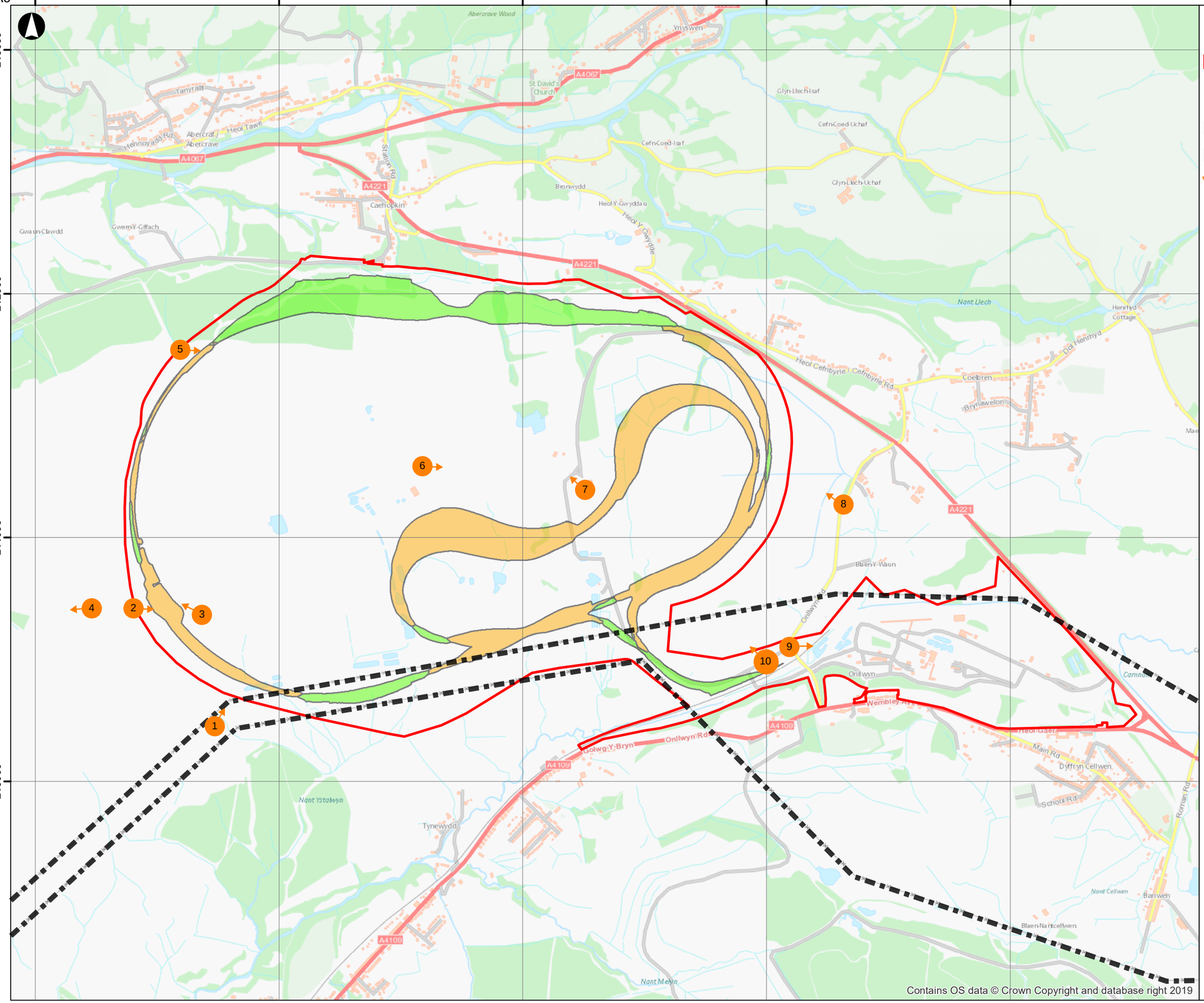

Legend

- Site Boundary

Indicative Extent of Proposed Earthworks

- Cuttings
- Embankments
- # Photo Location
- Overhead Electricity Cables

Coordinate System: British National Grid

Refer to Appendix A for site walkover photographs.

Metres

0 400 800

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Drawing Title
Site Walkover Photo Locations

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

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P1

Name
Figure 3

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A3

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213000 212000 211000 210000

Gwaunclawdd Colliery

Gwaunclawdd Colliery

Neath and Brecon Railway (Junction Line)

International Colliery

Abercrave Colliery

Unnamed Colliery

Glynllech/Cwm Tawe Colliery

Tramway

Tramway

Brecon Forest Tramroad

Neath and Brecon Railway

Dulais/Drym Colliery

Onllwyn Colliery

Seven Sisters Colliery

Legend

- Site Boundary
- Rail & Tram Lines
- Collieries

Indicative Extent of Proposed Earthworks

- Cuttings
- Embankments

Coordinate System: British National Grid

Colliery locations and rail/tram line routes have been determined through review of OS historical mapping (Groundsure).

Refer to Figure 8 and Figure 9 for the identified extents of underground workings and opencast workings respectively.

Metres

0 400 800

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Project Title
Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Select Historical Features

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

Rev
P1

Drawing No
Figure 4

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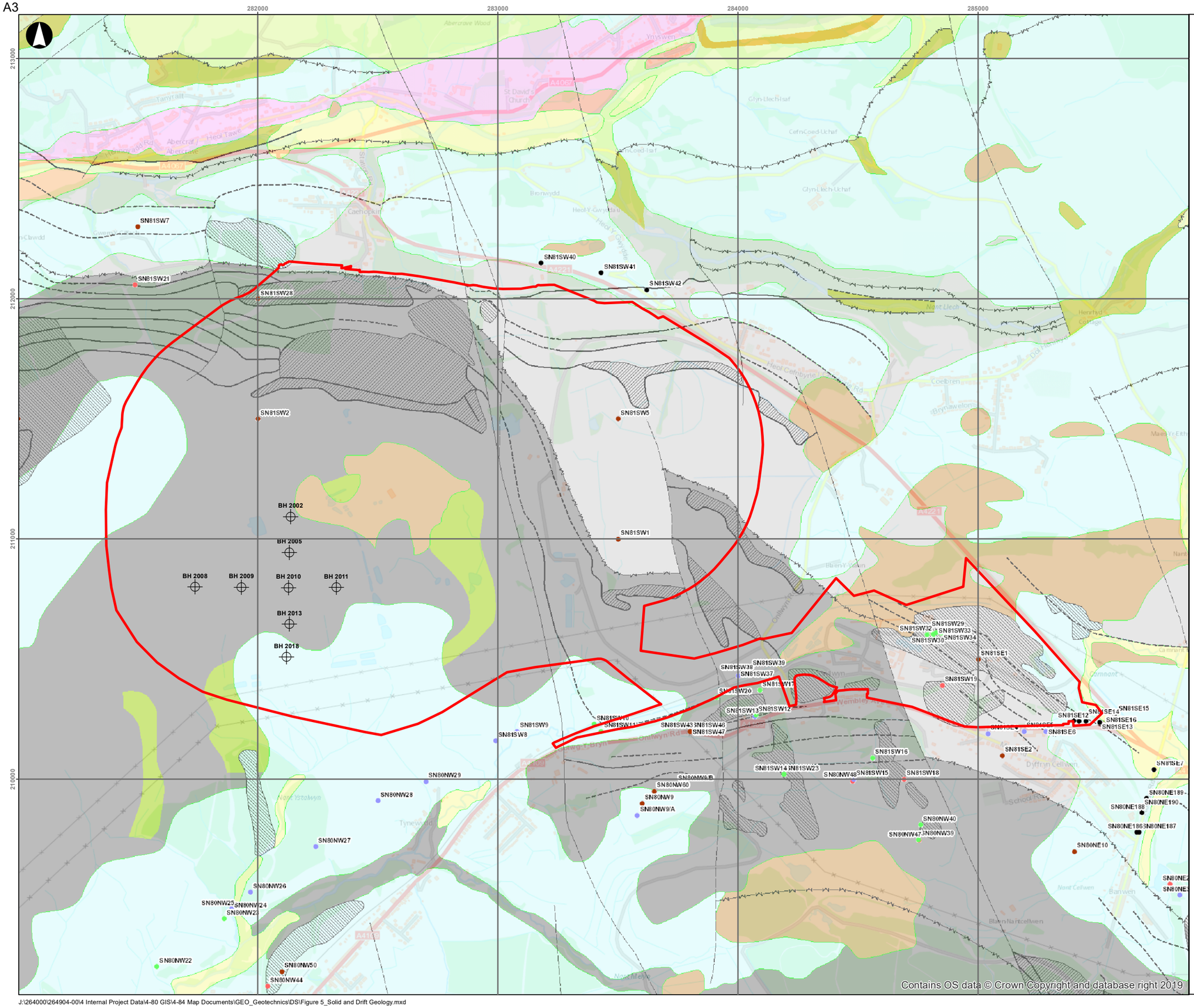

Legend

- Site Boundary

Published Geology

- Made Ground
- Alluvium
- Peat
- Glaciofluvial Deposits
- Glacial Till
- South Wales Middle Coal Measures Formation - Mudstone, Siltstone and Sandstone
- South Wales Middle Coal Measures Formation - Sandstone
- South Wales Lower Coal Measures Formation - Mudstone, Siltstone and Sandstone
- BGS Borehole Scans
- Nant Helen Geotechnical Boreholes (1986)

Coordinate System: British National Grid

Metres

0 400 800

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Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Solid and Drift Geology

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

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Rev
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Drawing No
Figure 5

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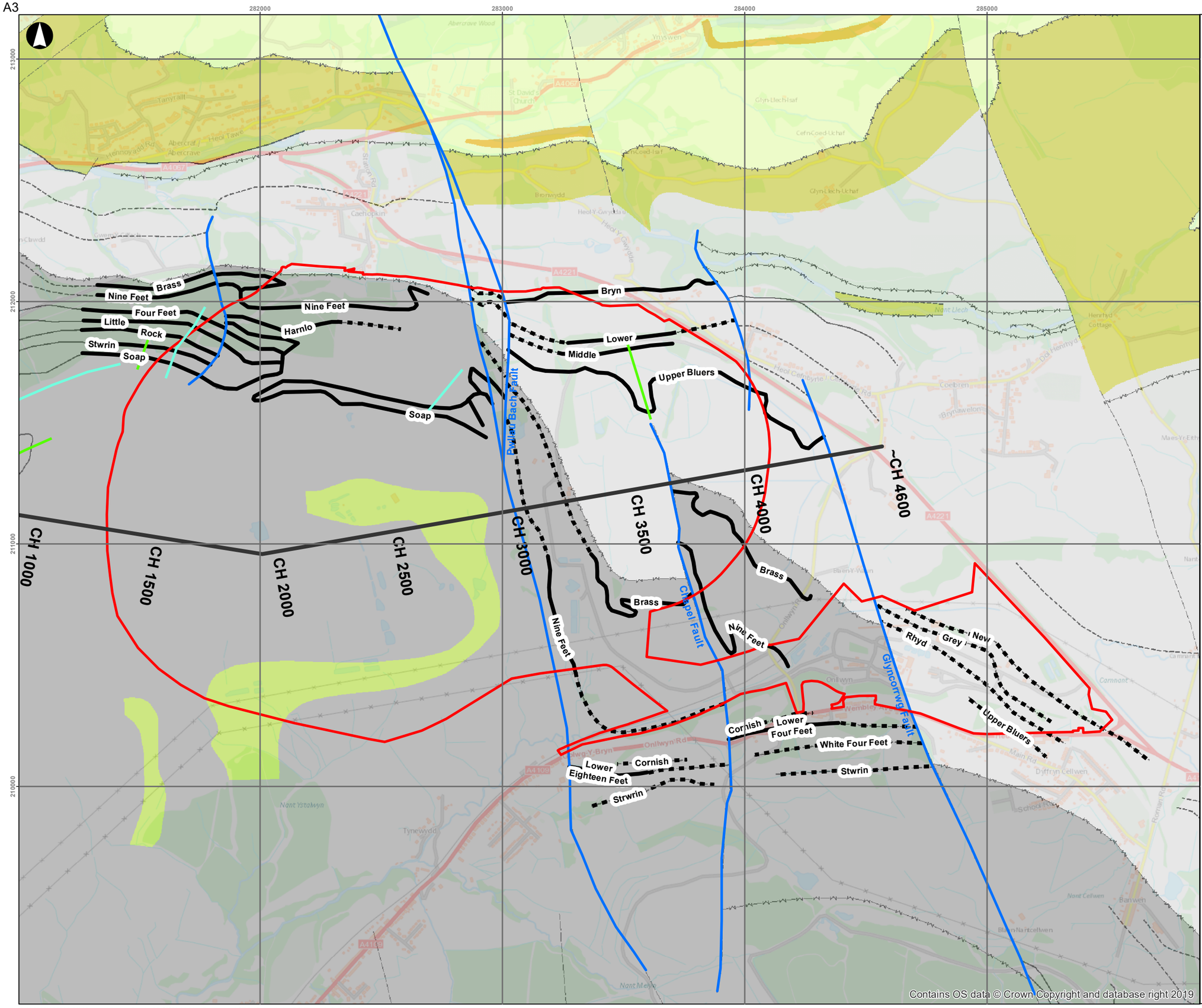
A3



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Legend

- Site Boundary

Coal Seams

- *Observed*
- *Inferred*

Published Geology

- South Wales Middle Coal Measures Formation - Mudstone, Siltstone and Sandstone
- South Wales Middle Coal Measures Formation - Sandstone
- South Wales Lower Coal Measures Formation - Mudstone, Siltstone and Sandstone
- Faults
- *Anticlinal axis*
- *Synclinal axis*

Coordinate System: British National Grid

Metres

0 400 800

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Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Linear Geological Features

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

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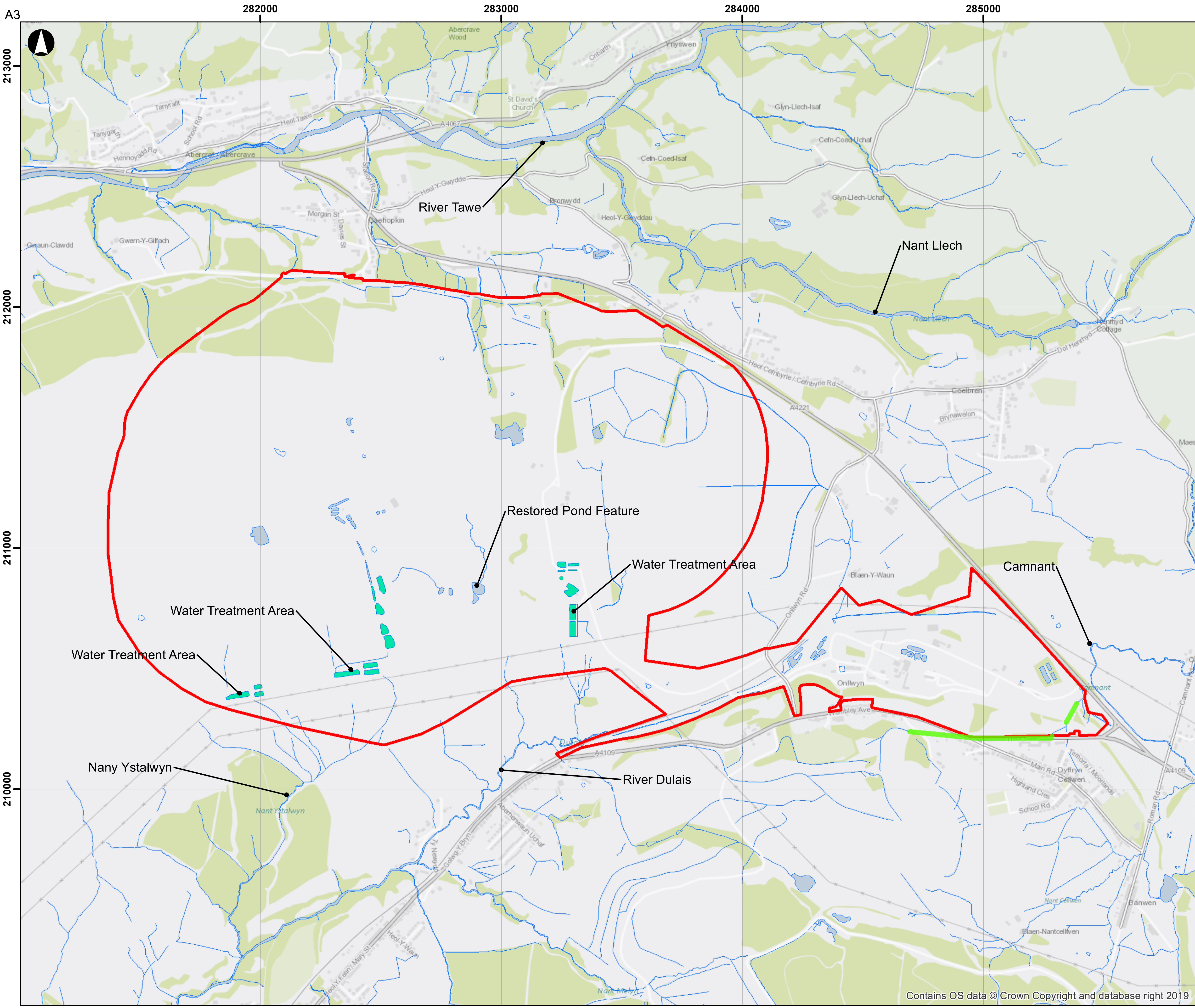
Rev
P1

Drawing No
Figure 6

A3



Legend

- Site Boundary
- Surface Water Features
- Culverted Watercourses
- Existing Water Treatment

Coordinate System: British National Grid

Metres
0 400 800

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Project Title
Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Hydrological Features

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

Rev
P1

Name
Figure 7

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A3

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213000 212000 211000 210000

Gwaunclawdd Colliery

Gwaunclawdd Colliery

International Colliery

Unnamed Colliery

Abercrave Colliery

RISK ZONE B

Glynllech/Cwm Tawe Colliery

RISK ZONE C

CH 3000

CH 3500

CH 4000

~CH 4600

RISK ZONE A

RISK ZONE D

CH 1000

CH 1500

CH 2000

CH 2500

G

H

E

F

B

A

C

C

D

Onllwyn Colliery

Seven Sisters Colliery

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Legend

- Site Boundary
- Shafts
- Adits
- Collieries
- Cuttings
- Embankments

Old Workings

- Brass
- Peacock (Brass)
- Nine Feet
- Big (Nine Feet)
- Unnamed

- Risk Zones — *Risk of subisdence on account of potential shallow workings*
- Figure 11 Section Line

Old workings have been geo-referenced from files provided by Celtic Energy. The extents shown are for indicative purposes only.

Coordinate System: British National Grid

Metres

0 400 800

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Project Title
Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Identifed extent of below ground workings

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

Rev
P1

Drawing No
Figure 8

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A3

282000 283000 284000 285000

213000 212000 211000 210000

Gwaunclawdd Colliery

Gwaunclawdd Colliery

International Colliery

Unnamed Colliery

Abercrave Colliery

RISK ZONE B

Glynllech/Cwm Tawe Colliery

Abercrave/Gwaunton

Nant Helen Extension

Nant Helen

CH 1000

CH 1500

CH 2000

CH 2500

CH 3000

CH 3500

CH 4000

~CH 4600

Onllwyn

RISK ZONE A

Onllwyn

Onllwyn Colliery

Dulais/Drym Colliery

RISK ZONE C

Seven Sisters Colliery

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Legend

- Site Boundary
- Collieries
- Shafts
- Adits
- Cuttings
- Embankments

Opencast Sites

- *Onllwyn (1946-1949)*
- *Abercrave/Gwaunton (1963-1973)*
- *Onllwyn (1972-1982)*
- *Nant Helen (1986-1999)*
- *Nant Helen Extension (2002-2006)*
- *Nant Helen Extension (2006-2009)*
- *Nant Helen Extension (2009-2019)*
- Cefn Bryle License Area *(1952-1953)*
- Risk Zones *Risk of subsidence on account of potential shallow underground mine workings*
- Figure 11 Section Line

Opencast site extents have been determined through review of Opencast abandonment plans provided by Celtic energy and cross-referenced with historical aerial photography provided by the Welsh Government. The extents shown are for indicative purposes only.

Coordinate System: British National Grid

Metres

0 400 800

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Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Identified extents of opencast workings

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

Arup Job No
264904

Rev
P1

Drawing No
Figure 9

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A3

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Brecon Beacons

NANT LLECH

GORSLLWYN, ONLLWYN

Ancient Semi Natural Woodland

Plantation on Ancient Woodland Site

Ancient Semi Natural Woodland

Plantation on Ancient Woodland Site

Tramroad at Ystradgynlais

Bryn Llechwen ring cairn

Legend

- Site Boundary
- National Parks
- Sites of Special Scientific Interest
- Ancient Woodland
- Scheduled Ancient Monuments

Indicative Extent of Proposed Earthworks

- Cuttings
- Embankments

Coordinate System: British National Grid

Metres
0 400 800

Rev	Date	By	Chkd	Appd
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Project Title
Land at Nant Helen and Onllwyn Coal Washery

Drawing Title
Sensitive Land Uses

Scale at A3
1:15,000

Role
Geotechnical

Suitability
For Information

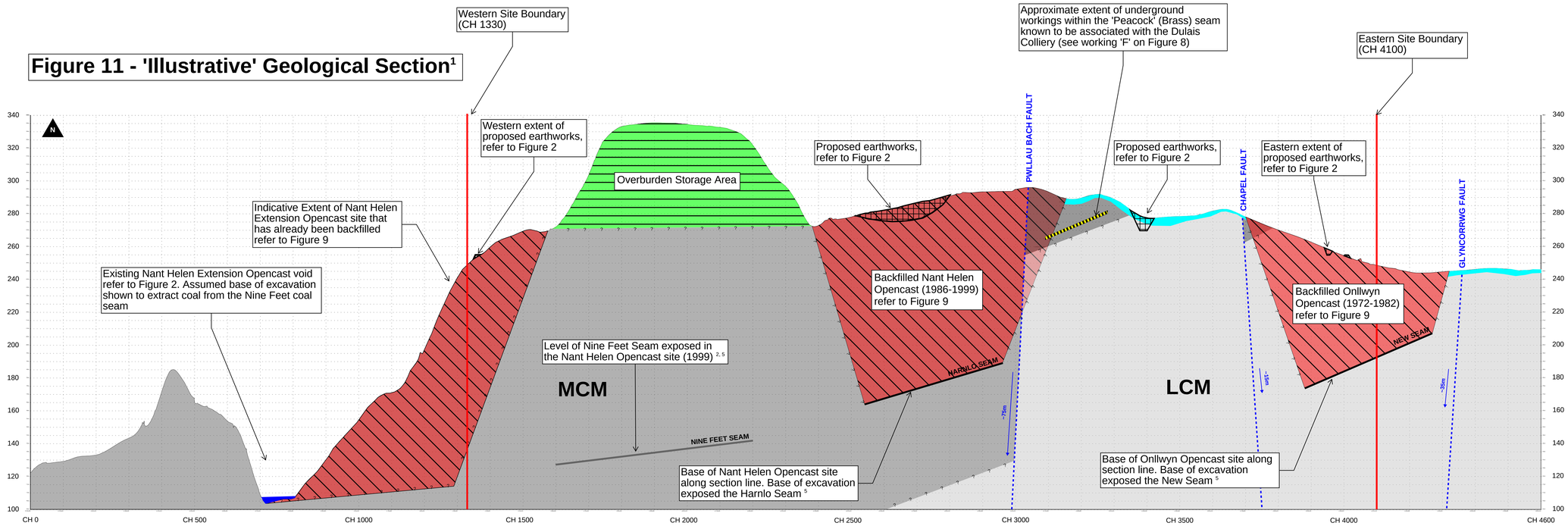
Arup Job No
264904

Rev
P1

Name
Figure 10

J:\264000\264904-00\4 Internal Project Data\4-80 GIS\4-84 Map Documents\GEO_Geotechnics\DS\Figure 10_Sensitive Land Uses.mxd

Figure 11 - 'Illustrative' Geological Section[1]



LEGEND

Geology

- Glacial Till
- South Wales Middle Coal Measures (MCM)
- South Wales Lower Coal Measures (LCM)
- Faults
- Coal Seams

Workings

- Overburden Storage Area
- Backfilled Opencast
- Underground Workings
- Proposed Earthworks (Cuttings and Embankments)

NOTES

1. This figure is for illustrative purposes only and has been included to highlight the anticipated geology beneath the site and the depths of the various opencast sites within the Land at Nant Helen and Onllwyn Coal Washery site.

2. The level of the Nine Feet Seam exposed pertains to a section of the Nant Helen opencast site which is offset approximately ~400m to the north of the long section shown.

3. Ground surface level from LiDAR data.

4. Fault orientations displayed for indicative purposes only. Fault displacements and directions indicated on each fault.

5. Coal Seams shown refer to those used to determine the indicative extents of opencast excavation. For an indication of the overlying and underlying seams within each formation refer to Table 3.

6. As stated within Section 5.3 of thisproposed earthworks, refer to figure 2 report, the solid geology beneath the site is anticipated to dip between 5° and 15° in a west-south-westerly direction.

7. Groundwater level not indicated on figure due to the anticipated complex and varied nature of the hydrogeological regime and the lack of current groundwater data held within the site. Refer to Section 8 of the report.

SCALE

V 1: 1000 @ A0

H 1: 5000 @ A0