Copperworks Discovery Project 2021

Heritage Lottery Funded Project

Archaeological Community Project at the Hafod-Morfa Copperworks

Prepared for

Swansea University & The City and County of Swansea

By

CRONFA DREFTADAETH HERITAGE FUND

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- BLACK MOUNTAINS ARCHAEOLOGY - - ARCHAEOLEG MYNYDD DU -

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Cover image: volunteers gathered on site of excavations at the former Hafod plate rolling mill

Summary

Gofynnwyd Archeoleg Mynydd Du Cyf gan Gofynnodd Dr Alex Langlands o Brifysgol Abertawe i gynnal prosiect archaeoleg gymunedol ar dir sy'n perthyn i Ddinas a Sir Abertawe yng Ngwaith Copr Hafod-Morfa, Abertawe (NGR SS(2)66167, (1)94925) . Mae'r prosiect yn rhan o'r Cynllun Datblygu Gweithgarwch a Chynulleidfa ar gyfer Prosiect Pwerdy Cronfa Dreftadaeth y Loteri Genedlaethol (NLHF) (HE-15-01729).

Mewn ymateb i'r brosiect a nodwyd gan Dr Alex Langlands, canolbwyntiodd y prosiect ar:

- *• Rhoi profiad cadarnhaol o archeoleg i bawb sy'n cymryd rhan, gan ganiatáu iddynt gymryd perchnogaeth o'u treftadaeth eu hunain.*
- *• Ymgysylltu ag ystod eang o grwpiau cymunedol sy'n pontio'r cenedlaethau fel oedolion agored i niwed a phlant ysgol yn y prosiect, gan hyrwyddo pwysigrwydd a gwerth treftadaeth leol yng Nghwm Tawe Isaf.*
- *• Cynyddu mynediad i sgiliau cyflogadwy ym maes archaeoleg ar gyfer grwpiau y tu allan i'r system addysg prifysgol, gan roi set sgiliau lefel mynediad o dechnegau archaeolegol i'r archeolegydd newydd y gallant adeiladu ohonynt.*
- *• Cynyddu ymgysylltiad y cyhoedd ag archeoleg ddiwydiannol yr ardal a'r rhaglen o weithgareddau a gynhelir trwy ymgyrch cyfryngau cymdeithasol digidol, postiadau blog a blogiau, a digwyddiadau ymgysylltu rhithwir cyn-cychwyn ac ar ôl cloddio.*

Roedd ymchwiliadau archeolegol yn cynnwys cloddio 6 ffos ar dir i'r de o'r Musgrave Engine House ar safle hen felin rolio rhwng Afon Tawe i'r dwyrain a ffordd ddosbarthu'r Morfa i'r gorllewin, at ddiben archwilio a chofnodi natur a'r maint unrhyw nodweddion archeolegol sy'n gysylltiedig â gweithgaredd diwydiannol yng ngwaith copr Hafod-Morfa. Yn ystod gwaith cloddio, darganfuwyd olion ffynnon boeth o'r 20fed ganrif yn Ffos 1, lle cafodd dŵr wedi'i ailgylchu o'r boeleri a oedd ynghlwm wrth y Musgrave Engine ei bwmpio i mewn; yn ogystal ag olion rhandy gorllewinol Melin Rholio Platiau'r Hafod. Yn Ffos 2, darganfuwyd y tu mewn i'r anecs gorllewinol a'r felin rolio platiau go iawn, yn ogystal â rhai sylfeini adeileddol o'r 19eg ganrif a oedd yn gysylltiedig â Gwaith Hafod cyn adeiladu'r felin rolio platiau. Yn Ffos 3, daethpwyd o hyd i weddillion ffwrnais anelio o ddechrau'r 20fed ganrif, yn ogystal ag olion y dehonglir yn betrus eu bod yn perthyn i bwll diffodd. Yn Ffos 4, darganfuwyd olion strwythurol sy'n gysylltiedig â thu allan rhandy'r felin rolio platiau. Yn Ffos 5, daethpwyd o hyd i du mewn y felin rolio platiau, gan gynnwys sylfeini peiriant gwastadu platiau. Yn olaf, o fewn Ffos 6 daethpwyd o hyd i sylfeini adeileddol sy'n gysylltiedig o bosibl â'r ty morthwyl o'r 19eg ganrif, yn ogystal â bwth diffodd o'r 20fed ganrif, a leolir o fewn terfynau'r felin rolio platiau go iawn.

Perfformir yr holl waith yn unol â Chodau a Safonau Proffesiynol y Chartered Institute for Archaeologists (CIfA), yn benodol y 'Standards and Guidance for Archaeological Excavation' (cyhoeddwyd 2014, diwygiwyd 2020) a 'Photogrammetric Applications for Cultural Heritage Guidance for Good Practice' gan Historic England (cyhoeddwyd 2017).

Black Mountains Archaeology Ltd were requested by Dr Alex Langlands of Swansea University to undertake a community archaeology project on land belonging to the City and County of Swansea at the Hafod-Morfa Copperworks, Swansea (NGR SS(2)66167, (1)94925). The project forms part of the Activity and Audience Development Plan for the National Lottery Heritage Fund (NLHF) Powerhouse Project (HE-15-01729).

In response to project aims identified by Dr Alex Langlands, the project aimed to:

- *Provide all participants with a positive experience of archaeology, allowing them to take ownership of their own heritage.*
- *Engage a broad range of intergenerational community groups such as vulnerable adults and schoolchildren with the project, promoting the importance and value of local heritage in the Lower Swansea Valley.*
- *Increase access to employable skills in the field of archaeology for groups outside of the university education system, providing the novice archaeologist with an entry-level skillset of archaeological techniques from which they can build.*
- *Maximise public engagement with both the industrial archaeology of the area and the programme of activities taking place through a digital social media campaign, blog and vlog posts, and pre-commencement and post-excavation virtual engagement events.*

Archaeological investigations comprised the excavation of 6 trenches on land to the south of the Musgrave Engine House on the site of a former rolling mill between the River Tawe to the east and the Morfa distributor road to the west, in order to examine and record the nature and extent of any archaeological features associated with industrial activity at the Hafod-Morfa copperworks. During excavations, the remains of a 20th century hot well were uncovered within Trench 1, into which recycled water from the boilers attached to the Musgrave Engine was pumped; as well as the remains of the Hafod Plate Rolling Mill's western annex. Within Trench 2, the interior of the western annex and plate rolling mill proper were uncovered, as well as some 19th century structural foundations associated with the Hafod Works prior to the construction of the plate rolling mill. Within Trench 3, the remains of an early 20th century annealing furnace were uncovered, as well as remains associated with a quenching pool. Within Trench 4, structural remains associated with the exterior of the plate rolling mill annex were uncovered. Within Trench 5, the interior of the plate rolling mill were uncovered, including the foundations of a plate flattening machine. Finally, within Trench 6 structural foundations possibly associated with the 19th century hammer house were uncovered, as well as a 20th century quenching bosh, situated within the confines of the plate rolling mill proper.

All works were performed to the professional codes and standards of the Chartered Institute for Archaeologists (CIfA)*, in particular their* Standards and Guidance for Archaeological Excavation (published 2014, revised 2020) *and* Historic England's Photogrammetric Applications for Cultural Heritage Guidance for Good Practice (published 2017).

Acknowledgements and Copyright

Black Mountains Archaeology Ltd is pleased to have been able to provide both financial and 'in-kind' support to this NLHF funded project. The project was managed by Richard Lewis BA MCIfA, supported by Abbi Wootten-Brooks BA PCIfA. The fieldwork was directed by Richard Lewis, Libby Langlands BA MA, Dr Rhys Morgan PhD and Abbi-Wooten-Brooks. The community aspects of the project were managed by Abbi Wooten-Brooks. The report was prepared by Dr Rhys Morgan PhD and Abbi Wootten-Brooks. The illustrations and Welsh translation were prepared by Dr Rhys Morgan. The 3D photogrammetric surveying was carried out by Richard Lewis, Libby Langlands and Dr Rhys Morgan. The 3D photogrammetric modelling was completed by Richard Lewis. The ceramic and glass finds were reported on by Joyce Compton. The post-excavation analysis has benefited significantly from the extensive research conducted by Libby Langlands for the adjacent Swansea Council and Penderyn

Whisky development of the former Powerhouse. Special thanks also go to the and the Friends of Hafod Morfa Copperworks, whose sustained interest in keeping the history of the copperworks alive has been an inspiration. Of the Friends, Tom Henderson in particular deserves particular praise, as he provided an in-depth interpretation of the hot well discovered during the project as well as providing us with Plates 89–97 and the YIM Uniflow Document. Finally, we would like to extend our sincere thanks to all of the fantastic volunteers who took part in the event (see Appendix VII).

 The project team would like to thank Dr Alex Langlands of Swansea University and Swansea Council for making the project possible, as well as all volunteers who took part. Indeed, it was their hard work that made the project such a success. We would also like to thank Jonathan Berry at Cadw for taking the time to visit the investigations. Last but not least, thanks goes to Tom Henderson for providing his interpretation of the hot well discovered in Trench 1 as well as his engineering expertise, which he offered throughout the project. Finally, special thanks goes to Arthur Green who kindly provided photographs of the Hafod works prior to demolition; Plate 88 has been reproduced with his kind permission.

	Name	**Date**
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1 Introduction

1.1 Project Background and Proposals

1.1.1 Black Mountains Archaeology Ltd/Archeoleg Mynydd Du Cyf were requested by Dr Alex Langlands of Swansea University to undertake a community archaeology project on land belonging to the City and County of Swansea at the Hafod-Morfa Copperworks, Swansea (NGR SS(2)66167, (1)94925) (Figure 1). The project forms part of the Activity and Audience Development Plan for the National Lottery Heritage Fund (NLHF) Powerhouse Project (HE-15-01729). The three principal project aims identified by Dr Langlands are as follows:

- To engage a diverse range of community members in the rich industrial heritage of the Lower Swansea Valley.
- To impart key entry-level skills from site safety to novice archaeological techniques.
- To make a digital record of the project (both the engagement and the archaeology) through mixed media comprising, but not limited to, social media posts, digital photographs, and film clips.

1.1.2 All works were undertaken in accordance with the professional codes and standards of the Chartered Institute for Archaeologists *(CIfA)*, in particular their *Standard and Guidance for Archaeological Field Evaluation* (published 2014, revised 2020) and Historic England's *Photogrammetric Applications for Cultural Heritage Guidance for Good Practice* (published 2017).

1.2 Objectives

1.2.1 The definition of an archaeological Field Evaluation as set out by the *Chartered Institute for Archaeologists* (CIfA) is a programme of non-intrusive and/or intrusive fieldwork which determines the presence or absence of archaeological features, structures, deposits, artefacts or ecofacts within a specified area or site on land, inter-tidal zone or underwater. If such archaeological remains are present the field evaluation defines their character, extent, quality and preservation, and enables an assessment of their significance in a local, regional, national or international context as appropriate.

1.2.2 The purpose of an archaeological Field Evaluation is to gain information about the archaeological resource within a given area or site (including its presence or absence, character, extent, date, integrity, state of preservation and quality), in order to make an assessment of its merit in the appropriate context, leading to one or more of the following:

- The formulation of a strategy to ensure the recording, preservation or management of the resource.
- The formulation of a strategy to mitigate a threat to the archaeological resource.
- The formulation of a proposal for further archaeological investigation within a programme of research.

1.2.3 (Chartered Institute for Archaeologists' *Standard and Guidance for Archaeological Field Evaluation*, published 2014, revised 2020)

1.3 Location, Topography and Geology

1.3.1 The former Hafod-Morfa Copperworks (NGR SS(2)66250,(1)95020) is located approximately 4km north of Swansea city centre on the banks of the River Tawe. Swansea is situated on Carboniferous Coal measures and the extraction of coal from this area has greatly influenced the history and development of the region. The soils over the study area are largely un-surveyed but are likely to include alluvium associated with the River Tawe and substantial peat deposits (SSEW 1983).

1.3.2 The bedrock within the area generally comprises deposits associated with the South Wales Upper Coal Measures formation, which is made up of Mudstone, Siltstone, Sandstone, Coal, Ironstone and Ferricrete and ranges between the geological ages of Westphalian D to the Bolsovian (West Phalian C) during the broader Carboniferous period. These deposits would have formed between 306–8 million years ago in an environment dominated by rivers which deposited sand, gravel, detrital material, silt, clay and some bogs. Superficial deposits within the development area are confined to clays, silts, sands and gravels, which would have been deposited in the Quaternary period approximately 2 million years ago (BGS 2021).

1.3.3 The site investigated during the Copperworks Discovery Project 2021 was situated immediately southwest of the Musgrave Engine and Rolls curtilage (SMGm483). The site once contained the Hafod rolling mill, erected in 1819, as well as a later plate rolling mill, possibly constructed in 1910 at the same time as the Musgrave steam engine was installed. Bounding the site to the east are the banks of the River Tawe. Running along the eastern edge of the site is a large retaining wall, above which the Landore Social Club is situated. The site is currently overgrown with thick vegetation and shallow-setting trees, most notably silver birch.

1.4 History and Archaeology

1.4.1 History of the Hafod-Morfa Copperworks

1.4.2 Swansea was one of the hubs of the industrial revolution in Wales and contained a series of works and mines built alongside the River Tawe from 1720 onwards. From the start, the new works concentrated on the smelting of copper, although other industries also evolved as a direct result. These other industries included the fire clay industry, which manufactured fire brick and refractory linings; the alum and salt industry; the pottery industry, which produced mainly earthenware and, for a short while, fine porcelain; as well as other metal industries such as those related to the production of iron, tin plate, and zinc. All these industries were reliant on coal which was initially transported by wagon before the construction of the Swansea Canal in 1794–96, which later became a vital conduit in supplying coal and other raw materials to these industries.

1.4.3 Both the Hafod and Morfa works were established on greenfield, if not virgin sites, shown as being empty on a 1777 map of the local area *(Plan of River Swansey in* Glamorganshire, by B Jones) but owned by the Duke of Beaufort, from whom the Hafod and Morfa sites were initially leased. A long field boundary, shown on an 1847

Tithe Map (*Map of the Parish of St John juxta Swansea, Glamorganshire*), persisted as the boundary wall between the two sites until the 1980s (Ludlow 2002, 14). The Hafod Copperworks were established in 1808–09 by the Cornish entrepreneur John Vivian (1750–1826) with his sons John Henry Vivian (1785–1855) and Richard Hussey Vivian (1775–1842). Later in 1835, a Cornish firm, Williams, Foster & Co., opened the Morfa Copperworks on adjacent land. The Vivians, in conjunction with other Cornish industrialists such as Michael Williams and Pascoe Grenfell, took over the majority of Swansea's smelting industry throughout the first decade of the 19th century (Hughes 2000, 35).

1.4.4 John Vivian was involved in business at an early age. He was a wine and lime merchant in partnership with William McCarmick in Truro until 1777 before beginning his involvement in the metal industry. His initial role in the copper trade was in Cornwall where he worked as an agent for the copper magnate Thomas Williams and the Staffordshire Cheadle Brass and Wire Company, purchasing copper ore from the mines in the county on their behalf and arranging for its shipment to their smelting works in South Wales.

1.4.5 Sometime close to 1800, John Vivian, who was now representing the associated miners of Cornwall, visited Swansea to investigate the conditions of copper smelting as a profitable occupation. In 1800, he became a partner in the Cheadle Brass and Wire Company, whose copper smelting works were at Penclawdd, to the west of Swansea. This marked the beginning of the Vivians' involvement in copper smelting in Wales. In 1808, he resigned from the Cheadle Brass and Wire Company to start his own company in partnership with his sons at Hafod. The Hafod site chosen by Vivian lay between the Swansea Canal to the west and the River Tawe to the southeast, allowing for efficient water transport of raw materials to the site, both by canal barge from the upper Swansea Valley and by ship from elsewhere in Britain. In addition, by 1810 a dedicated canal basin had been constructed at the northern end of the works, to offload coal from the barges into the works. The venture undertaken by Vivian and his sons was soon established as a major manufacturer of copper in Britain. Within ten years Vivian and Sons was the second largest producer of copper in Britain, accounting for about 17% of national output and by the mid-19th century was the largest copperworks in the world.

1.4.6 The Hafod site continually modernised, changed and expanded, with a rolling mill being added to the smelters sometime in 1819 for making bars and plates from copper ingots. Facilities were constantly improved over the course of the century, to enable the works to increase output and adopt improved technology; the prime obstacle became the lack of available land on which to maintain this expansion program, with the site becoming progressively cramped. Increased production led to an increased amount of waste that needed to be disposed of. Eventually, in 1865, with the construction of a new tramroad, the company was able to transport waste slag over the canal to the west, therefore releasing more areas for site development. The pressure created by the amount of waste slag was also partly eased by casting this waste material into usable blocks for building with. The company ceased smelting, and therefore the creation of slag waste, on site in 1904.

1.4.7 By the mid-19th century, the neighbouring Morfa Copperworks was now well established and being run by Williams, Foster & Co. who started the company in 1828, running it until 1880. The Morfa Copperworks were built next door to the Hafod works with only a high stone wall between the two to divide them. Legend has it that workers at Morfa were instructed not to talk to the Hafod workers for fear of giving away trade secrets. Work at Morfa began in 1828 with the construction of a rolling mill to process the ingots produced by the Rose Copperworks in Plasmarl, before its copper smelting facilities were added in 1834–35. The Morfa Copperworks became the largest non-ferrous metal smelter in the world by the mid-19th century, employing over 1,000 people and supplying the Royal Mint with its copper. By 1861, Michael Williams had grown from a leading partner in Williams, Foster and Co. to having almost complete control of the business until his death in 1880. At this time, it was also said that Williams was the richest man in Cornwall. The Hafod and Morfa works amalgamated in 1924 and were subsequently operated by Yorkshire Imperial Metals. These new works, the Hafod-Morfa Copperworks, closed in 1980, when it was the last operating copperworks in Swansea.

1.4.8 Both the Hafod and Morfa works were situated in the Lower Swansea Valley along with more than eleven other copperworks, which gave rise to the name Copperopolis. This area, by the mid–late 19th, century accounted for 90% of the world's copper production (Hughes 2000). Swansea was key to the global copper industry and, by 1823, 10,000 of Swansea's 15,000 residents were supported by the copper industry within the 124 copperworks or related industries. The rise in this vast industry was made possible by a plentiful supply of coal in the Swansea Valley, brought down to the copperworks via the late 18th century canals. In addition, both the port at Swansea and the River Tawe, being navigable inland along its deepest three tidal miles, could carry sailing-ships up to the thirteen main smelting works built alongside the river. It was these excellent and easily accessible facilities for shipping which allowed the import of copper ore from Cornwall, North Wales, South America and Australia, along with the easy export of finished metal.

1.4.9 **Archaeology within the Local and Surrounding Area**

1.4.10 The White Rock Copperworks (SMGm481) was established in 1736 and was one of the most important copper smelting works in the Lower Swansea Valley. White Rock was the third oldest of the Swansea copperworks, established by a partnership from Bristol at a time when copper smelting was switching from blast furnace to reverberatory furnace technology. The works closed in 1924 and the site was almost completely cleared in the 1960s by the army. Industrial remains include the revetment wall of the 1736 'Great Workhouse', kilns, furnaces, flues and a 17th century river dock flanked on the north by a series of later stone-built quays, with decks made of cast blocks of copper slag. In 1870–71, lead and silver smelting was introduced, and this resulted in the building of a brick condensing flue at the side of Kilvey Hill and an inclined railway to remove spoil. Part of the latter was supported by a stone arch that also housed two flues and a chimney, which still survives today (Hughes and Reynolds 1988; Hughes 2000).

1.4.11 The earliest transport route in the area was Chauncey Townsend's wooden horse-drawn wagonway, built in 1756 in order to connect the collieries of Llansamlet and

Birchgrove with his copperworks at Middle and Upper Bank, as well as his dock at the White Rock Copperworks. Townsend brought the Newcastle-based railway engineer George Kirkhouse to Swansea, and over 27 years they built in excess of thirteen miles of wooden tracked railways across land he leased in the Llansamlet and Gwernllwynchwyth coalfields (Hughes 2000, 82–96).

1.4.12 In 1783, the Smith's Canal was built by John Smith to transport coal from his collieries at Llansamlet. This privately owned canal largely replaced Townsend's earlier wooden surface wagonway. The canal stretched for 2.1km, from Llansamlet to the coal staithes (SMGm482) on the River Tawe at Foxhole and remained in use until 1852. The canal passed underground through the White Rock Copperworks in a cut-and-cover tunnel, together with underground wharves behind the Great Workhouse, where coal was offloaded directly into the furnaces (Hughes and Reynolds 1988; Hughes 2000, 96–102).

1.4.13 Several tramroads were constructed between 1816–19 to connect the collieries of John Scott, a London solicitor, in Llansamlet to the docks at the White Rock Copperworks and the Foxhole coal staithes. Scott's Tramroad (NPRN403886) was built to carry coal from Scott's Pit (SMGm336) to the docks and followed the course of Smith's Canal on its eastern side down to the Foxhole coal staithes. A George Stephenson locomotive may have worked the line for a short period. In 1828, the colliery and tramroad were sold to Charles Henry Smith of Gwernllwynchwyth, who also used a locomotive on the line in 1833 (Hughes and Reynolds 1988).

1.4.14 In 1845, the Swansea Vale Railway (SVR) (NPRN418157) acquired the tramroad with a view to modernising and connecting it to the Swansea Docks with the proposed Midland Railway. By 1860, a passenger service between St Thomas' station in Swansea and Pontardawe had been established and the line was extended to Brynamman in the northern coalfield in 1864. The Midland Railway began by leasing the SVR in 1874, before purchasing it two years later. Passenger traffic ceased in 1950 and the line closed in stages between 1964–83 (Barrie 1994, 205–9; Hughes and Reynolds 1988).

1.4.15 At least fifteen or more significant structures, in varying degrees of condition, survive across the Hafod-Morfa Copperworks site. These include the former Morfa Rolling Mill (LB16878), now used as a museum stores; the Laboratory Building (LB11690); and the former Morfa Powerhouse and later Yorkshire Imperial Metals Canteen (LB11691). The Hafod Limekiln (LB11694); Copper Slag Abutment, Pier and Canal Boundary Walls (LB11692 and 11693); the Vivian Engine House (LB11695); the Chimney west of the Vivian Engine House (LB11696); and the Boundary Wall for the Hafod Copperworks canal docks (LB16881) are also situated within the immediate vicinity, as well as the *in-situ* Musgrave Engine and Rolls (SMGm483) in the Musgrave Engine House and Chimney (LB11697).

1.4.16 **Site Specific History and Archaeology**

1.4.17 The site investigated during the Copperworks Discovery Project 2021 was situated immediately southwest of the Musgrave Engine and Rolls curtilage (SMGm483). This monument comprises a recently restored Musgrave steam engine (house), rope drive and travelling crane, which was connected to a sizeable plate rolling mill situated to its south and west. The Musgrave steam engine was installed in 1910 and was of the

uniflow type, meaning that steam passed through its cylinders in single direction without reversals between strokes. The steam was transferred into its cylinders via inlets at each end, with exhaust valves located towards the centre of the cylinder. The engine was constructed by the Bolton-based John Musgrave and Sons and was one of the first engines of its kind to be built in Britain. It also represented a state in the art of steam technology for its time. The Musgrave engine house survives at full height and the engine itself is situated towards its north-eastern half and is set within a concrete base. A square-based chimney is also situated within the monument, which stands at 27m in height. The Musgrave steam engine powered the Hafod plate rolling mill, situated immediately to its east and south, most of which lies beyond the limits of the Scheduled Monument. However, the north-eastern end of the plate rolling mill is situated within the monument's curtilage, the remains of which comprise machinery associated with the initial stages of plate rolling. This machinery is situated to the southwest of the Musgrave steam engine's flywheel. The Hafod plate rolling mill was rectangular in form and exceedingly large in size, measuring approximately 110m in length x 17m in width, not including the elongated annex building attached to its western edge.

1.4.18 The Hafod plate rolling mill was probably erected in 1910 in conjunction with the installation of the Musgrave steam engine. However, this plate rolling mill replaced a far older rolling mill which, according to Hughes' speculative plan of the copperworks (Figures 11–12) was significantly smaller in size, covering the area immediately east of the Musgrave engine house. This rolling mill, known as the No 1 Mill, was erected in 1819. The layout of the No 1 Mill is detailed in Plate 84, in which a row of four rolls is depicted running through the centre of the building. These rolls, from northernmost to southernmost, include the bolt rolls, large finishing rolls, finishing rolls and breaking rolls. From north to south, the spacing between these rolls became consecutively smaller, meaning that copper slabs could be fed through each in turn in order to achieve sections of copper that were sufficiently thin. Running along the westernmost side of the building were a corresponding series of annealing furnaces, and it appears that sections of copper were placed within these furnaces immediately prior to being fed into their corresponding set of rolls. For example, copper would be placed into the 'Furnace for the Bolt Rolls' before being fed into the bolts rolls, or the 'Furnace for the Large Finishing Rolls' before being fed into the large finishing rolls, and so on. Also incorporated into the westernmost side of the building was an engine house, within which a Neath Abbey engine sat. By 1842, a second rolling mill was erected – the No 2 Mill – immediately to the north of the first one. To the southwest of the No 1 Mill was the Hammer House, within which sections of copper were hammered flat and even, possibly after being transferred from the No 1 and 2 Mills. This operation was achieved via the use of large, vertically set steam hammers. The precise date at which the No 1 and 2 Mills, as well as the Hammer House, were demolished is unknown, although their demolition can be assumed to have taken place sometime prior to the erection of the later Hafod plate rolling mill and the installation of the Musgrave steam engine in 1910.

1.5 Previous Archaeological Investigations

1.5.1 2002 – a desk-based assessment was produced by GGAT for the Landore Park and Ride scheme. The assessment identified 21 extant buildings and the location of fourteen demolished buildings associated with Hafod-Morfa Copperworks site.

1.5.2 2002 – a site appraisal was produced by Dyfed Archaeological Trust in order to establish management plans for the identifiable heritage assets at the Hafod-Morfa Copperworks site.

1.5.3 2004 – an archaeological watching brief was undertaken by GGAT during the excavation of ground contamination test pits. A total of 18 test pits were excavated across the site of the copperworks. Some of the test pits confirmed a depth for natural on this site, whilst other test pits revealed solid structures.

1.5.4 2004 – a building survey was undertaken by GGAT on a section of the Swansea Canal wall that was to be demolished to make way for a bus lane.

1.5.5 2008 – a desk-based assessment was undertaken by Cambria Archaeology on the area of the Hafod-Morfa Copperworks. This assessed the current condition of all buildings and features on the site and revised the individual building management plan.

1.5.6 2008 – an environmental impact assessment was undertaken by Cambria Archaeology for the Morfa Distributor Road, which was intended to follow the line of the southern section of the Swansea Canal as it passes through the Hafod Copperworks.

1.5.7 2013 – GGAT were commissioned by Swansea University to undertake a community archaeological excavation of the Hafod Copperworks. Three trenches were excavated: Trenches 1 and 2 were both abandoned as a result of contamination and Trench 3 was excavated to examine the approach to the works via the canal bridge to the main entrance.

1.5.8 2015 – GGAT were commissioned to carry out a watching brief on six geotechnical pits in advance of the construction of Morfa Distributor Road, Swansea. A number of Post-medieval deposits were uncovered and likely related to the partial demolition of the Morfa Copperworks and the infilling of the Swansea Canal.

1.5.9 2015 and 2016 – Rubicon Heritage conducted archaeological investigations ahead of the construction of the Morfa Distributor Road. A series of evaluation trenches was excavated together with supplementary works.

1.5.10 In the spring of 2018 and on behalf of Swansea University, Black Mountains Archaeology Ltd delivered a very successful community history and archaeology project at the world renowned Hafod-Morfa Copperworks. The Copperworks Discovery Project provided opportunities to get involved with historical and archaeological research workshops to explore the copperwork's past and on-site building survey workshops. The community project formed part of the wider regeneration project that aims to turn the renowned copperwork site into a world class heritage, innovation, and education destination. Further information can be found with this link.

1.5.11 2018 – Black Mountains Archaeology Ltd conducted an archaeological field evaluation for Swansea Council on three parcels of land within the Hafod-Morfa copperworks

area (Eyre-Morgan and Morgan 2021). Twelve evaluation trenches were strategically excavated across the site of the former copperworks in three defined areas, to achieve the most comprehensive understanding of the archaeological potential of the site. Trenches 1–3 (Area B) were targeted over the canal dock and the western end of the powerhouse/boilers of the Morfa works; Trenches 4–6 (Area A) were targeted over the Long House furnaces (and calcining furnaces); Trenches 7–9 (Area A) were targeted over the ore yards and later buildings housing a Bessemer converter; and Trenches 10–12 (Area C) were targeted to the south of the rolling mills and gasworks. Area C fell within the perimeter established for the proposed community archaeology investigation and informed the location of trenching. Cross-referencing the findings of this trenching with historic plans of the copperworks strongly suggested that the footprint of the Number 1 Rolling Mill was uncovered during the investigation. The results of the evaluation on the wider copperworks site revealed a deep layer (>2m) of waste and debris overlying extensive archaeological remains of the former copperworks. The archaeological remains included: the floors and walls to various buildings, culverts, reverberatory furnace bases, machine bases and various foundation layers. The overlying debris and waste were the result of copper production and the demolition of the copperworks. However, the overlying waste material in the location of the proposed community archaeology investigation was found to be fairly shallow (c. 0.3-0.4m) reflecting the position of *in-situ* floors associated with the Number 1 Rolling Mill.

1.5.12 2019 – Black Mountains Archaeology Ltd conducted a survey of timber design patterns found discarded in the basement of the Powerhouse for Swansea Council (Lewis and Cook 2019). The basement floor of the Powerhouse building was cleaned and a 3D photogrammetric survey was carried out to produce a comprehensive record of the timber design patterns held within for archival purposes and to provide for further study and research. Many hundreds of pieces of timber were either too fragmentary, unidentifiable or in such degraded state that survey was impracticable. However, despite the challenges a total of 97 timber objects including 39 design patterns were recorded together with five fully measurable 3D photogrammetric models. The floor was composed of rectangular worn ceramic bricks, uneven in places due to subsidence. This floor was contemporaneous with the construction of the Powerhouse building but built over the back-filled pond, which may have been causing the subsidence.

1.5.13 2019 – Black Mountains Archaeology Ltd were commissioned by the City & County of Swansea to carry out an archaeological watching brief during ground investigation works by Hydrock of a derelict area in between the Powerhouse (LB11691) and Rolling Mill (LB11691) buildings on the former site of the Hafod-Morfa Copperworks (. A quarry tile floor relating to the 1920s 'Cloakroom and Bath' noted in the 1939 ICI plan was discovered and found to survive across all three test pits within the area enclosed by the revetment wall. Beneath this floor a substantial masonry structure constructed of limestone bonded with lime mortar was uncovered, surviving across the three test pits. The structure is believed to relate to the earlier building recorded on the 1st Edition Ordnance Survey map. Another two test pits situated adjacent to the weighbridge office uncovered the north, east and west walls of the weighbridge first marked on the 1953 Ordnance Survey map. A further two test pits in the area above

the revetment wall also uncovered an E/W continuation of the revetment wall and the foundations of the Porter's Lodge. Further to these test pits, two boreholes were hand excavated followed by percussion drilling and cable drilling. A borehole log recording the nature and depths of deposits was taken. In one of the boreholes the south wall of the weighbridge was uncovered. The position of the drill was repositioned to avoid this feature. The depth of the canal basin floor was noted at 3m below present ground surface.

1.5.14 2019 – Black Mountains Archaeology Ltd conducted an archaeological field evaluation for Swansea Council on the Silverstack Canal Bridge, Hafod-Morfa Copperworks and Smith's Canal, White Rock Copperworks (Lewis and Langlands 2019). An open excavation (clearance) was carried out around the basse of the demolished Silverstack Canal Bridge and five trenches were machine excavated along the Smith's Canal followed by hand clearing and recoding. The investigations identified the remains of the Silverstack Canal Bridge abutments and the canal walls belonging to the Smith's Canal.

1.5.15 2019 to 2020 – Black Mountains Archaeology Ltd conducted an archaeological strip, map and record (SMR) for Swansea Council of land to the south of Swansea Museum stores and west of the Powerhouse to inform on the nature and extent of any archaeological remains in advance of the construction of a whiskey distillery and visitor centre. Among the principle discoveries were the remains of a large pond (labelled number 46 on historic maps) (Area 1), the well-preserved remains of an early 20th century bath house (Area 2) and the west and north walls of the Yellow Metals Mill Cast House within which were discovered a WWII air raid shelter and a series of early 19th century furnaces (Area 4). Furthermore, a large, culverted water filtration system was discovered to the north of the weighbridge office in Area 5. The remains of one of the early Morfa Rolling Mill buildings was recorded (area 3), known to have burned down in 1840. A long-forgotten WWII memorial was revealed on the gable end of the surviving building. The east gable end of the original Morfa Laboratory building was found on the western edge of Area 3, along with a large stone and brick tunnel running from the corner of the Yellow Metals Mill Cast House to the Morfa Rolling Mill, likely to be an early walkway or tramway. Moreover, the remains of a reverberatory furnace was discovered in Area 3, within the footprint of the Yellow Metals Mill Cast House.

1.5.16 2020–ongoing – Black Mountains Archaeology Ltd is currently conducting an archaeological watching brief for Swansea Council during the construction phase of the above-mentioned whisky distillery and visitor centre. Keys discoveries include the remains of a reverberatory furnace towards the southern end of the Yellow Metals Mill Cast House, as well as a hot gas flue associated with the reverberatory furnace discovered during the SMR. Excavations to the east of the Morfa Powerhouse building uncovered a 19th century hot gas flue that was seen to run in a broadly E/W direction towards the large flue feeding into the Silverstack chimney. The remains of a series of 19th and 20th century buildings were also uncovered here which, according to a late 19th century plan of the works, may have been a series of workshops. Along the southern edge of the Morfa Powerhouse the remains of an incline tramway were uncovered, with a further section of *in-situ* tramrail observed to the east of the building. To the west of the Morfa Powerhouse, groundworks revealed the full depth

of the large pond that predates the construction of the Powerhouse, as well as two brick relief arches within the western gable wall of the Powerhouse building. Excavations on the upper terrace uncovered the footings for a large Lancashire boiler, probably used in the 20th century to store oil or fuel.

2 Methodology

2.1.1 The Copperworks Discovery Project 2021 comprised a field evaluation of the study area, situated immediately southwest of the Musgrave Engine and Rolls Scheduled Monument (SMGm483). This field evaluation involved the excavation of six trenches (Figures 1–2). These trenches were as follows:

- Trench 1: positioned 1.4m from the south-western perimeter of the Scheduled Monument, measured 21.3m long x 2.2m wide with a small extension at its northwest end measuring 3.4m x 2.8m, and was targeted over the annex attached to the western edge of the Hafod plate rolling mill.
- Trench 2: positioned towards the south of the site, measured 16.1m long x 2.2m wide, and was targeted over the core of the Hafod plate rolling mill.
- Trench 3: positioned in parallel alignment and to the east of Trench 1, measured 14.7m long x 2.4m wide, and was targeted over the core of the Hafod plate rolling mill.
- Trench 4: positioned towards the bas of the retaining wall separating the study from Morfa Road to the west, measured 3.9m long x 1.9m wide, and targeted over the annex attached to the western edge of the Hafod plate rolling mill.
- Trench 5: positioned towards the centre of the study area, was irregular in form (covering an area of 37.1m^2) and was targeted over the core of the Hafod plate rolling mill (Eventually, Trench 5 was extended to join up with Trench 6).
- Trench 6: positioned immediately south of Trench 5, measured 13.8m long x 1.9m wide, and targeted over the core of the Hafod plate rolling mill (Eventually, Trench 6 was extended to join up with Trench 5).

2.1.2 An HER Enquiry was submitted to GGAT on the 22nd November 2021 encompassing the copperworks of the Lower Swansea Valley, which was received on the 2nd December 2021 (HER Ref. 6703). The information provided by this HER Enquiry greatly aided the process of interpreting the results of the field evaluation. Furthermore, it should be stated that the lengthy research undertaken for the watching briefs, SMR and field evaluation commissioned by the City & County of Swansea for the proposed Penderyn site to the north (detailed above) also aided the project. In particular, research of historic maps helped determine which structures and features had previously occupied the site, which in turn aided in determining trench locations.

2.1.3 All trenches were laid out using a EMLID GNSS/Glonass (GPS) Receiver and data logger with a <20mm tolerance. All trench areas, spoil tips and areas of archaeological potential were CAT scanned.

2.1.4 Plant was provided in the form of a JCB-sized excavator with a 1.8m wide grading bucket. All trenches were machine excavated and then cleaned by hand before being recording in detail. The archaeological recording techniques conformed to the best industry standard. All significant archaeological deposits were recorded with a single continuous context numbering system pro forma. Contexts were drawn at a suitable scale in plan and in section (1:20 in plan and 1:10 in section). All significant contexts were photographed in digital at 24mp and the images archived in TIFF format. Excavations were located and benchmarked to the Ordnance Survey.

2.1.5 All trenches were photographed in high resolution by a DSLR camera. All 3D models were produced using proprietary photogrammetry software and aligned using known ground control points (GCPs). Dimensional control were applied to each model and then reprocessed using the new parameters and optimised cameras to create dense point cloud and a high face count mesh. Models were then exported to OBJ format. GCPs operated within a sub-20mm error margin to OSGB36 (National Grid) and a high-resolution Ground Sampling Distance (GSD). High resolution orthographic renders (orthoplanes and orthomosaics) were exported and scaled in georeferenced raster (TIFF and JPEG) format.

2.1.6 The models are interactive and measurable (measure a line, area or volume). The inspect tool (icon = ⌖) is particularly useful, click anywhere on the 3D model and it will show the corresponding geographic information (NGR and Datum).

Trench 1:

https://cloud.pix4d.com/dataset/1082727/map?shareToken=6552ed0e-2626-484e-b2fb-97a93917036d

Trench 2:

https://cloud.pix4d.com/dataset/1081790/map?shareToken=ad6c51ac-2083-4315-b913-a71b63c25bc9

Trench 3:

https://cloud.pix4d.com/dataset/1083995/map?shareToken=6ed26197-c1bb-4bed-94f1-2cd0522cf6ec

Trench 4: https://cloud.pix4d.com/dataset/1082939/map?shareToken=2d1c979d-9e53-45a5-b518-fb95861f22d6

Trenches 5 and 6:

https://cloud.pix4d.com/dataset/1083768/map?shareToken=3f4c4272-3b10-493c-aa68-de4cbe4915a3

2.1.7 The capture, processing and output of 3D models conformed to the professional industry standard and best practice guidelines as set out by Historic England's *Photogrammetric Applications for Cultural Heritage Guidance for Good Practice* (published 2017).

2.1.8 The archaeological field evaluation was carried out to the standards set out by the Chartered Institute for Archaeologists' *Standard and Guidance for Archaeological Field Evaluation* (published 2014, revised 2020).

3 Results

3.1.1 The archaeological field evaluation consisted of the excavation of six trenches (Trenches 1–6) (Figures 1–2), the results of which are detailed below. Contextual information pertaining to each trench can be found in Appendix III.

3.1.2 The entirety of the study area was covered by a thick demolition deposit which contained, most notably, masonry, brick, metal and concrete in a dark brown silty clay matrix. Within each trench, this demolition deposit has been assigned a context number specific to the trench. In Trench 1 it is known as (101); in Trench 2 it is known as (201); in Trench 3 it is known as (301); in Trench 4 it is known as (401); in Trench 5 it is known as (501); and in Trench 6 it is known as (601). However, a general number has also been given to this deposit outside of the trench locations, which is (001). In terms of its dimensions, this deposit was seen to measure anywhere between 0.1–0.9m in depth. Within this deposit, the base of a glass jar/bottle and a sherd of transfer-printed ware was collected (see below).

3.2 Trench 1

3.2.1 Trench 1 was NE/SW aligned and its north-eastern edge was positioned 1.4m from the south-western perimeter of the Musgrave Engine House and Rolls Scheduled Monument (SMGm483). Initially, the trench was linear in form, measuring 21.3m in length x 2.2m in width. However, the discovery of the eastern wall of hot well [141] towards the northeast end of the trench meant that a small westward extension was excavated, measuring 3.4m x 2.8m, for the purposes of determining the extent of this feature. The final form of Trench 1 was, therefore, broadly L-shaped. On the northeast end of the trench, significant flooding was encountered, both within the confines of hot well [141] and within the area immediately beyond its eastern wall. This flooding was caused by ingress from the water supply system that hot well [141] was connected to, which only subsided when the water levels within the hot well and the area beyond its eastern wall reached equilibrium. As a result, excavations towards the northeast edge of Trench 1 terminated at the point at which this equilibrium in water level was attained. The height at the top of the trench was recorded at 7.1mOD at its south-western end and 6.94mOD at its north-eastern. The height at the base of the trench varied significantly. At the southwest end of the trench the base measured 6.9mOD. The base of excavations at the northeast end (beyond the eastern wall of the hot well) was not determined due to the aforementioned flooding, although the height at which the flood water levelled off was recorded at approximately 6.24mOD. With the aid of an extendable staff, the base of the hot well was determined to be approximately 2.5m deep, meaning that it was situated at around 4.44mOD. In total, the area covered by Trench 1 was 54.86m^2. The average depth of excavation was 0.6m.

3.2.2 **Stratigraphic Evidence**

3.2.3 The archaeological features uncovered within Trench 1 can be divided into two main areas. The first area, which extended approximately 14.3m north-eastward from the southwest edge of the trench, represented the western wall of an annex attached to the western end of the main plate rolling mill building, and associated features. The second area, which comprised an area extending approximately 7m south-westward from the northeast edge of the trench, represented the remains of a hot well, pump

chamber, and associated features. Apart from where specified otherwise, all archaeological features uncovered within Trench 1 directly underlay demolition deposit (101), which comprised fragments of demolition material, most notable masonry, brick, metal and concrete in a dark brown silty clay matrix. The maximum depth of this deposit was 0.9m – a measurement taken from the north-eastern end of the trench – however the maximum depth of the deposit throughout most of the trench was approximately 0.3m.

3.2.4 Western Wall of Hafod Plate Rolling Mill Annex (Figures 1–3; Plates 1–9)

3.2.5 The western wall of the plate rolling mill annex was represented by wall [123]. This wall extended in a NE/SW direction through the centre of the trench before terminating at a concrete structure [102], which formed the hot well and pump chamber. Immediately overlying the wall was demolition deposit (101), which also abutted the wall on its western edge. Although the structural remains of wall [123] were absent within this area of the trench, the relationship between wall [123] and concrete [102] was determined. The distribution of concrete [102] in this area respected the foundation of wall [123], meaning that it was deposited after the erection of the wall. In terms of dimensions, wall [123] measured 0.24m wide and although significant stretches of this wall were missing upon excavation, it was seen to measure 14.3m in length before continuing south-westward beyond the limits of the trench. In terms of its composition, wall [123] was composed of frogged red bricks in conjunction with some older, re-used unfrogged bricks, red and orange in colour. These re-used bricks had traces of grey, ashy lime mortar attached to them, suggesting that they originally derived from a demolished building of 19th century date. The mortar bonding wall [123] together comprised grey cement. The depth of the wall was not determined, although excavations revealed its two uppermost courses. Observation of these courses revealed that the wall comprised a stretcher bond. The wall was also seen to be two stretchers wide. The bricks comprising the wall, in general, measured 0.24m long x 0.15m wide x 0.12m deep. These were the precise dimensions of the later frogged bricks, which were contemporary with the construction of the wall. With regards to the older, re-used bricks, it appeared that these were cut to these approximate dimensions before being set in place. The north-eastern limit of wall [123] was demarcated by the base of RSJ [122], which was abutted on its northern and western edges by concrete [102]. The flanges of this RSJ were aligned in a NE/SW direction, meaning that the web of the RSJ originally covered the entirety of the width of wall [123]. In plan, this RSJ measured 0.25m long x 0.15m wide. An additional RSJ was discovered approximately 1.5m to the northeast of here, which was also abutted by concrete [102], on its western edge. This RSJ, numbered [120], was identical in form, orientation and size to [122] and was also associated with wall [123]. Immediately west of RSJ [122] was a small circular foundation set within concrete [102], numbered [121]. In plan, this foundation measured 0.45m in diameter and likely represented the remains of a vertical rail leading into pump chamber [142]. To the south of [121] was an additional foundation, numbered [137], which was identical in form and diameter. This feature likely also formed part of the same railing.

3.2.6 Towards the western and eastern edges of wall [123] were, in respective order, the exterior and interior of the plate rolling mill annex. The interior was only partially observed, as represented by concrete floor [134], which abutted wall [123] on its

eastern edge. This concrete floor measured 0.5m wide before running eastward beyond the limit of the trench, while its visible length was 3.14m. The section of floor [134] revealed in the trench represented only a small section of the floor in its entirety as it was found in a significantly demolished state. Originally, this floor would have likely extended along the entirety of the eastern edge of wall [123]. Approximately 0.3m southwest of concrete [134] was rubble deposit (136), which directly overlay the southernmost stretch of wall [123]. This rubble deposit comprised fragments of red brick, both frogged and unfrogged, and although amorphous in shape was situated mostly towards the eastern edge of wall [123]. This deposit measured at most 1m in width before running beneath the easternmost edge of the trench, while in length it was seen to measure 2.1m. In depth, this deposit was notably shallow, measuring no more than 0.1m.

3.2.7 On the western (exterior) edge of wall [123] was a series of drainage features and some additional walling foundations, all of which were situated directly below demolition deposit (101). Towards the south-western edge of the trench was drainage gully [135], which abutted the western edge of wall [123]. This gully was composed of at least five sections of pre-moulded concrete, although the degrees of disturbance that this feature sustained, which were significant, meant that determining its precise structure and form proved difficult. In profile, this gully was concave with two projecting lips on either side, each no more than 0.1m wide. From southwest to northeast, the gully respected the orientation of wall [123] before turning slightly westward beyond the trajectory of the wall. This westward turn was traced for approximately 0.6m, although beyond this point the gully had been completely removed. In width, gully [135] measured 0.3m, while its surviving length was 2.4m. Approximately 3m to the northeast of gully [135] was an additional gully, numbered [133]. This gully also respected the trajectory of wall [123], running in a NE/SW direction. Although also composed of concrete, this gully differed in form to gully [135], as its concave profile was significantly shallower and wider. It also appeared that this gully was moulded as a single piece, rather than constituting multiple sections. This gully, furthermore, incorporated only a single lip, located on its eastern edge, abutting wall [123], which again measured no more than 0.1m wide. Ostensibly, the western edge of the gully incorporated no lip. In terms of its overall dimensions, this gully measured 0.39m in width, while its surviving length measured 2.3m. Approximately 4.8m southwest of the north-eastern limit of wall [123] were the remains of manhole [129], composed of frogged bricks, red in colour, which were bonded with a grey cement mortar. Each of these bricks was also stamped with the label ‘National Star Newport’ and measured 0.24m long x 0.11m wide x 0.07m deep. These types of bricks were being produced from the 1960s and 1970s onwards. Manhole [129] was square in form, covering an area measuring $1m^2$. The walls of the manhole were one header in thickness and were constructed in a stretcher bond. The fill of this manhole comprised demolition deposit (101), however immediately above this fill, directly within the confined of the manhole, was a possible manhole cover, numbered [130]. This possible cover was badly damaged but appeared to have originally been broadly square in form. In terms of its position, it had fallen into the manhole at an angle, while demolition deposit (101) had fallen in on top of it and into the manhole itself. This possible cover was formed of grey concrete, very coarse in

texture. It should be mentioned that this feature may not have been a cover and instead constituted a fragment of concrete rubble that had fallen into manhole [129]. Abutting the eastern edge of manhole [129] was a single line of edging tiles, numbered [131]. These tiles were bonded into the manhole with grey cement mortar, were yellow in colour and were notably thin, measuring no more than 0.07m in width. They were, moreover, unfrogged and were very poorly fired, possessing a sandy and friable texture. These tiles were noted only on the eastern edge of manhole [129], and they extended in a NE/SW direction for approximately 1.16m, marginally beyond the south-western and north-eastern edges of the manhole. Abutting the north-eastern edge of manhole [129] was concrete skirting [139], measuring 0.25m in width. This concrete skirting ran in an E/W direction for 1.1m, before turning northward and continuing for approximately 1.6m. The easternmost edge of this skirting was also seen to abut the western edge of wall [123]. On the north-eastern edge of this skirting deposit was concrete floor [125], which also abutted the western edge of wall [123]. This floor was very coarse in texture, and heavily damaged. Sandwiched in between skirting [139] and floor [125] was a single concrete slab, numbered [126], measuring 0.4m x 0.32m in plan, which was possible set in place during repair work to the latter. The concrete of this slab could be differentiated from that of floor [125] not only by its clearly definable edges but also by its texture, which was significantly less coarse. Also discovered within this small area was deposit (128), which comprised a clean and homogenous yellow sand. This deposit was confined to the northeast of manhole [129], which it abutted, and southwest of skirting [139], which it also abutted.

3.2.8 Abutting the north-eastern edge of gully [133] and the south-western edge of manhole [129] was a deposit of broken concrete slabs, numbered (132), covering a visible area of approximately 1.35m by 1m. The full extent of this deposit could not be determined, as immediately to its east was a layer of soil intermixed with a fine, powdery substance, numbered (145), covering an area of approximately 1m x 0.9m. For health and safety reasons, neither this substance nor the soil surrounding it was excavated. This substance was, however, seen to overlie the eastern edge of deposit (132), meaning it obscured the point at which it was possible to determine whether this deposit continued eastward beyond the limit of the trench. In width, from east to west, deposit (132) measured approximately 1m. In considering the way in which the concrete slabs comprising deposit (132) were positioned within the ground, which were all angled in a downwards position, it appeared as if they were infilling a linear foundation slot. Moreover, the southern and northern limits of deposit (132) appeared to comprise a pair of parallel lines, indicating again that this deposit was situated within a linear cavity. In plan, this possible foundation slot ran in an approximately SE/NW direction, beyond both the western and eastern limits of the trench. This feature has been interpreted here as the possible remains of a demolished or robbed out wall foundation, numbered [144].

3.2.9 <u>Discussion</u>

3.2.10 Together, the archaeological features detailed above formed the western edge of the annex attached to the western side of the Hafod plate rolling mill. As detailed in the 1946 aerial photograph of the site (Figures 23–24), the south-western half of Trench 1 was positioned directly over the western wall of this annex, represented by wall [123], which ran in a NW/SE direction for approximately 25m before reaching a

westward return, which represents the southernmost wall of the pump chamber. It should also be noted that the annex in its entirety covers a sizeable stretch of the mill, and according to the 1946 aerial photograph it appeared to have measured approximately 60m NE/SW x 10m WNW/ESE, not including the hot well housing, which extended a further 5m beyond the western wall of the annex. The Musgrave engine house is also shown to form part of this annex, which has been incorporated into its north-eastern corner. The 1939 and 1945 plans of the site (Figures 14–15 and Figures 18–21) also corroborate the information provided by the 1946 aerial photograph. However, Figures 21–22, which comprise plans of the site dating to at least 1926, shows the annex as being significantly smaller in size. This plan indicates the position of the plate rolling mill and Musgrave engine house with a small structure measuring approximately 16m long x 1m wide connecting the two. As this structure shares the same form and dimensions as the stretch of the annex immediately northeast of the hot well housing, it can be assumed that this structure represents the initial form that the annex took. In other words, the western annex of the plate rolling mill began as a small structure connecting the rolling mill to the Musgrave engine house before being extended south-westward, during which time the hot well housing and the stretch of wall [123] uncovered in Trench 1 were constructed. The construction of both the rolling mill and Musgrave engine house provide the erection of the annex (in its initial form at least) with a *terminus post quem* of 1910, while Figures 21–22 indicate that it was extended sometime after 1926. In Figures 11–12, the position of Trench 1 is indicated as running through the eastern edge of the 19th century Hafod Hammer House. As the plate rolling mill partly transects the southeast corner of this building, it should be assumed that the latter was demolished prior to the construction of the former and that it had already been demolished by the time this particular plan of the works was drawn. The fact that the Hammer House was included in this plan likely indicates that the plan was continually redrawn as the works developed. The remains of the Hammer House were not encountered during the excavation of Trench 1. If these remains were indeed present, they would have been situated at a level significantly deeper than that which was obtained during excavations.

3.2.11 Structurally, the western wall of the annex, as represented by wall [123], was notably diminutive in width and meagre in construction. It also appeared that a series of vertically set RSJs, of which two survived in the form of [120] and [122], provided the majority of the wall's structural support. The materials associated with wall [123], therefore, merely represented an infilling of material between these RSJs. Aside from concrete deposit [134], which formed the interior of the rolling mill annex, the remainder of the features uncovered within the south-western half of Trench 1 served as drainage attached to the guttering of the wall and roof of the annex.

3.2.12 <u>Hot Well and Pump Chamber (Figure 1–3; Plates 10–14)</u>

3.2.13 Due to the presence of trees in the area covered by the northern quarter of Trench 1, the hot well was only partially uncovered, while the position of the pump chamber could only be inferred. Both the hot well and pump chamber were formed of a single deposit of poured concrete, numbered [102]. In form, this concrete deposit comprised the side walls of a large, sunken bay measuring 3.9m in width by approximately 8m in length, within which the hot well and pump chamber were housed, in its north-eastern

and south-western halves respectively. The walls of this bay measured 0.9m in width, aside from a large section towards the north-eastern end of wall [123], where it formed a floor-like surface extending approximately 0.8m east of the bay comprising the hot well and pump chamber. In addition, the rear (southwest) wall of the large bay was markedly narrow, measuring 0.15m in width. Shutters were used in the forming both the large bay and attached floor-like surface, as demonstrated by the projecting vertical edges observed running along the eastern side of the hot well, which demarcated the positions of the shutters. These shutters appeared to have comprised large panels, none of which were left *in-situ*. The hot well and pump chamber housed within the large bay have been numbered [141] and [142] respectively. Hot well [141] was infilled with demolition material (138), which was similar to deposit (101) aside from the fact that it comprised very large fragments of rubble including, most notably, several sections of plastic pipe. Once uncovered, the hot well was seen to be significantly flooded. As detailed above, this flooding was caused by ingress from the water supply system that the hot well [141] was still connected to. Efforts were made to remove the flood water and deposit (138) from within the hot well via machine excavation, which was successful in removing the majority of deposit (138) but swift water ingress meant water levels remained relatively high within the hot well [141]. However, the excavations did establish that the base of the well was situated approximately 2.5m below the top of its north-eastern wall – a measurement that was obtained by lowering a telescopic levelling staff into the flood water. The ingress of water into hot well [141] derived from at least two points – inlet pipe [103], which entered the hot well from its northernmost wall, and outlet pipe [104], which exited the hot well through its easternmost wall. Both pipes were primary features, as concrete [102] was poured around and above them after they had been set in place. Pipe [103] was set approximately 1m above the floor of the hot well, while pipe [104] was positioned at a slightly higher level, approximately 0.8m below the top of the easternmost wall of the hot well. In terms of dimensions, the diameter of these pipes could not be ascertained as neither could be accessed safely, however, it was observed that both were formed of cast iron. Most of the juncture between hot well [141] and pump chamber [142] remains presumably buried *in-situ* and no partition wall separating the two was noted. As has already been mentioned above, the rear wall of the pump chamber [142] was observed to the southwest helping define the full extent of both the pump chamber and hot well ([141 and 142]. Defining the southern edge of pump chamber [142] was wall [140], which measured over 0.5m in length x 0.2m in width. This wall was formed of a concrete slab that was demonstrably separate from concrete [102], which it abutted on its western edge.

3.2.14 On the tops of the western and eastern walls of the large (hot well) bay, set directly into concrete [102], were a small series of notches, each measuring around 0.15m by 0.18m in plan by 0.17m deep. These notches likely indicated the points at which a corresponding series of horizontally set RSJs covered the top of the bay. Two notches were recoded within the western wall of the bay, which from south to north are numbered [106] and [105], while four notches were recorded within the eastern wall, which from north to south are numbered [107], [108], [109] and [110]. No further notches were observed within concrete [102] to the southwest of [110], while the area to the southwest of notch [106] was unexcavated. The large bay comprising concrete

[102], therefore, consisted of a rectangular aperture that had a setting of RSJs covering its north-eastern half, but not its south-western half. From this evidence, in conjunction with the available cartographic evidence, it may be inferred that half covered by the setting of RSJs was hot well [141], while the other half represented pump chamber [142]. Moreover, the RSJs within the eastern wall of the large bay end at the point where concrete [102] widened eastward to form the apparent floor-like surface detailed above, implying that its south-western half (the pump chamber) was designed to be approached by foot from the east, and possibly even entered from this side, while its north-eastern half (the hot well) was not. Finally, a small cut was recorded within the top of the rear wall of pump chamber [142]. Unlike the notches set within the side walls of hot well [141], this cut was made after concrete (102) had set and was narrower in size, measuring 0.1m in width. This cut, numbered [124], has been interpreted as having facilitated the entry of an electric cable into pump chamber [142], which may well have powered the pumps. The presence of this cable can only be inferred, as it did not survive *in-situ*. Immediately southwest of cut [124] was an additional cut, numbered [127], which was set directly into concrete floor [125], immediately to the northeast of manhole [129]. This cut was identical in width to that of [124] and was directly in line with it. It appeared that cut [127] held the same electrical cable, which allowed it to run in a N/S direction towards the southern corner of pump chamber [142], before additional cut [124] allowed the cable to enter the chamber itself. The fact that [124] was cut into concrete [102] after it had set indicates that the electric cable was a secondary addition to pump chamber [142].

3.2.15 Immediately beyond the eastern walls of hot well [141] and pump chamber [142] was a series additional features, all of which were related to water supply and drainage. The lowermost of these features was concrete [111] and steel cover [112], the former of which covered pipe [104] as it exited hot well [141], and the latter of which likely covered an inspection chamber providing access to the pipe. Concrete [111] measured approximately 0.7m in width by at least 0.85m in length and was formed via the aid of steel shutter [119] situated on its south-western edge, which was found *in-situ*. The true extent of steel cover [112] was not observed, as it continued eastward beyond the limit of the trench, although it was recorded as 0.83m in width by approximately 0.02m in thickness. The inspection chamber that it likely covered was not observed due to flooding. Approximately 0.2m northeast of steel cover [112] was an additional steel plate, numbered [118], although unlike [112], this piece of steel appeared to be situated directly above a small cavity that ran eastward beyond the limit of the trench. Neither the extent nor profile of this cavity could be ascertained due to flooding. In considering this, steel plate [118] has been interpreted as a lintel topping a drain or culvert that facilitated the removal of flood water from the area immediately east of hot well [141]. To where this drain/culvert led to is unknown, yet while this area of the trench was being flooded, flood water was entering the trench via this feature. In width, steel plate [118] measured approximately 0.75m, while in thickness it was no more than 0.02m. Approximately 1.5m to the southwest of concrete [111] was culvert [115]. This culvert ran in a broadly N/S direction, beneath the floor-like section of concrete [102]. This culvert also appeared to empty into the area immediately east of hot well [141], within which concrete [111], and therefore outlet pipe [104], were situated. In profile, this culvert comprised a lintel, numbered [114], topping an eastern

and western side wall, numbered [116] and [113] respectively. Lintel [114] was composed of two bricks, one sitting directly on top of the other, which were very large in size, measuring 0.54m long by 0.28m wide by 0.13m deep. These bricks were unfrogged, yellowish in colour and fairly sandy in texture. These bricks were also covered in pitch, presumably a waterproofing measure for the culvert. The side wall [116] was found in a highly disturbed state, although it was observed that in its original form it was composed of unfrogged bricks, again covered in pitch. This observation was based on a single brick that remained *in-situ*. The other side wall [113] was far better preserved, owing to the fact that it was composed of concrete. This wall directly abutted, and was therefore later than, concrete [102], situated immediately to the west in the form of the eastern wall of hot well [141]. In terms of its visible dimensions, wall [113] measured 0.64m long by 0.3m wide by 0.54m deep. The fill of culvert [115], which was situated directly between lintel [114] and side walls [116] and [113], and which extended southward beneath concrete [102], comprised black silt with frequent amounts of clinker and oil/pitch throughout. This fill is numbered (117). The cavity that this deposited infilled, in profile, measured at least 0.5m wide by 0.3m deep. The final feature to be detailed here is concrete floor or base [143]. This floor/base was only partially and momentarily observed, as immediately after it was revealed it became submerged in flood water. This concrete floor was situated between culvert [115] and concrete [111], yet its extent was not determined.

3.2.16 Discussion

3.2.17 The function of hot well [141] and pump chamber [142] has been discussed by Tom Henderson below. In his report Henderson provides a level of technical expertise that is beyond the scope of this particular section. In summary, Henderson explains that the hot well constituted an integral part of the Musgrave steam engine as it served as a reservoir that stored newly condensed water in such a way that it could be kept at a consistently high temperature, therefore increasing the efficiency of the steam engine as a whole. The water within the hot well would then be recycled, as it was pumped northward, back into the boilers attached to the Musgrave steam engine. The archaeological evidence indicates that the hot well and pump chamber was a later addition to the Musgrave engine, as both are formed of concrete with a base of Portland cement – a material that was not in common use during the installation of the engine in 1910. Henderson argues that the construction of the hot well dates between 1945 and 1958. This is supported by the available cartographic evidence. The first plan of the works in which the position (and indeed existence) of the hot well and pump chamber dates to 1945 (Figures 15–16). In this plan, the position of the hot well is merely proposed. However, it is important to note that in this same plan the pumping chamber is drawn in detail, suggesting that it had already been constructed, which would indicate that the construction of the hot well was either already underway or was about to be undertaken at this time. Therefore, it is suggested here that the pumping chamber possesses a *terminus ante quem* of 1945, while the hot well possesses a *terminus post quem* very close to, if not within, 1945. The hot well was incorporated at this time in order to increase the efficiency and capacity of the Musgrave steam engine and plate rolling mill that it was attached to. In this sense, it was a vitally important and integral component of the operations at the plate rolling mill as a whole.

3.3 Trench 2

3.3.1 Trench 2 was broadly E/W aligned and was positioned towards the southern edge of the investigation area, 2m south of Trench 6. The trench was linear in form, measuring 16.1m in length by 2.2m in width. The height at the top of the trench was recorded at 7.04mOD at its western end and 7.28mOD at its eastern. The height at the base of the trench was recorded at a uniform 6.56mOD. In total, the area covered by Trench 2 was 33.52m^2. The average depth of excavation was 0.64m.

3.3.2 **Stratigraphic Evidence**

3.3.3 The archaeological features and deposits uncovered within Trench 2 were associated with both the core and annex of the Hafod plate rolling mill. Broadly, the stratigraphic evidence of Trench 2 can also be divided into three sections – the annex of the plate rolling mill, as represented by the features uncovered at the western end of the trench; the core of the plate rolling mill, as represented by the features uncovered towards the centre of the trench; and the deposits and features on the eastern end of the trench. Apart from where specified otherwise, all archaeological features uncovered within Trench 2 directly underlay demolition deposit (201), which comprised fragments of demolition material, most notable masonry, brick, metal and concrete in a dark brown silty clay matrix. The depth of this deposit ranged from 0.26m to 0.8m.

3.3.4 <u>The Plate Rolling Mill Annex (Figures 1–2, 4 and 8; Plates 15–19)</u>

3.3.5 At the base of the western end of Trench, concrete [203] was uncovered, which either represented a floor surface or a sub-base that originally underlay a floor surface. The concrete comprising [203] was notably coarse in texture and contained frequent fragments of brick throughout. In consideration of this coarse texture, as well as its relationship with later floor surface [206] and [203] has been interpreted here as a sub-base. In terms of its visible dimensions, concrete [203] measured at least 1.2m E–W by 1.1m N–S. It must be stated, however, that concrete [203] was discovered in a highly disturbed and ruinous state, meaning that only a partial view of its original form was obtained. Abutting the north-eastern edge of concrete [203] was timber board [204], which was set on its edge. This board served as a shutter during the pouring of concrete [203]. This board was observed in a disturbed state, although its dimensions were broadly ascertained. In total, this board was seen to measure 0.7m long by 0.1m wide by 0.07m deep. Approximately 0.03m to the northeast of timber board [204] was timber post [205]. This post was again uncovered in a heavily disturbed state and only its base survived *in-situ*. This post had been set in place prior to the deposition of concrete [203], which was poured around it. When observed in plan, timber post [205] was broadly square to rectangular in form, measuring 0.4m by 0.3m. To the southwest of concrete [203] was foundation [207]. This foundation may have represented a machine base, although this interpretation is tentative. Only the corner of this feature was observed and the remainder of it extended beyond the southern limit of the trench. In terms of form, this possible machine base was composed of concrete and its visible dimensions were 0.17m x 0.29m x 0.1m deep. A void, either square or rectangular in form, was also set into this concrete, which may have served as a foundation for a vertical architectural member. Within this void was fill (208), which

comprised clinker and colliery waste in a matrix re-deposited natural comprising a mid-orangey brown silty clay. In section it was observed that this feature sat directly above concrete [203]. Sitting directly above concrete [203] as well as foundation [207], and below demolition deposit (201), was a deposit of black clinker, numbered (202), measuring 0.09m deep.

3.3.6 Discussion

3.3.7 The features and deposits uncovered at the western end of Trench 2 were situated directly within the confines of the annex attached to the western edge of the rolling mill, as indicated by the 1946 aerial photograph (Figures 23–24) as well as the 1939 and 1951 plan (Figures 14 and 15) of the works. As discussed above this annex was likely constructed in 1910 and in area covered a relatively small area surrounding the Musgrave Engine House. It was also stated above that the annex was extended south-westward towards the area covered by Trench 2 sometime after 1926. On the 1939 plan (Figures 13–14), the position of a gantry crane is indicated, the foundations for which were likely situated within an area covered by the western end of Trench 2. It appears that this gantry crane had the capacity to move in a NE/SW direction along this particular stretch of the rolling mill and was likely used for the transportation of copper plates to and from the rolls and other associated features within the mill building. The 1939 plan also seems to indicate that the transition between the main building and annex at this particular location was seamless, with little (if any) sign of partitioning. The crane is shown as extending westward towards the direction of the plate flattening machine and shears, the foundations of which were uncovered in Trenches 5 and 6. In being an overhanging feature, the presence of subterranean foundations associated with this gantry crane will naturally be limited. However, it appears that the western end of Trench 2 was positioned broadly in line with the south-western end of the gantry crane, and it is possible that some foundations were position within this area. These foundations would have presumably held steel members, in the form of RSJs, in place. It is possible that foundation [207] represented one such foundation. More specifically, the void that was partially witnessed within this foundation may have been the foundation for a vertical architectural member, such as an RSJ. Yet such an interpretation is highly tentative, and it is equally likely that foundation [207] represented the remains of a machine base or other structure. The placement of timber post [205] within this area is also difficult to interpret, although its position would suggest that it was associated with foundation [207].

3.3.8 The Core of the Plate Rolling Mill (Figures 1–2 and 4; Plates 15–26)

3.3.9 Immediately east of concrete [203] was an additional deposit of concrete, numbered [206]. This concrete was relatively fine in texture, which contrasted with the coarse texture of [203]. There were brick inclusions throughout concrete [206] as well, yet these were again far finer than those within concrete [203]. In depth, concrete [206] measured 0.09m, while from east to west it measured at least 3.9m. Stratigraphically, concrete [206] was situated directly above concrete [203], and the intersection between the two was only visible by virtue of the fact that, towards the western end of the trench, the former had been removed during the demolition of the site, revealing the latter underneath. It may be assumed, therefore, that concrete [203] extended eastward, beyond the visible limits of concrete [206]. Set directly into floor

[206] were a pair of features, which included, from west to east, timber [209] and linear foundation [210]. Timber [209] comprised a plank measuring 0.9m long by 0.07m wide before running beneath the northern section of the trench, while its alignment was NW/SE. In terms of its precise function, timber [209] is difficult to determine. It may have acted as a shutter during the pouring of concrete [206], although its position within the concrete, which was flat to the floor rather than on edge, seems to negate this hypothesis. Moreover, concrete [206] extended well beyond the position of timber [209], meaning that the latter failed to confine the former to a specific area, as a shutter would have done. Alternatively, it may have formed the south-western edge of a machine or other such feature. Linear foundation [210] was situated 0.4m to the southeast of timber [209] and was broadly rectangular in form. This feature was set directly in concrete [206], meaning that it was formed as the concrete was being poured. Although heavily disturbed, this foundation was seen to measure approximately 0.98m long by 0.25m wide by 0.1m deep. In terms orientation, this foundation was aligned in a broadly E–W direction. It was observed that foundation [210] had been partly infilled by concrete deposit (211), which was similar in appearance to [206], but slightly coarser in texture. Functionally, little can be said of foundation [210], primarily as no additional features were discovered set within it. However, in considering the position of this foundation, which was set directly within the confines of the plate rolling mill, it could have represented part of a machine base. Alternatively, its linear form may suggest that it originally comprised a sliding rail attached to a machine. The fact that foundation [210] was later infilled by concrete (211) seems to suggest that at some point during the use of the plate rolling mill, the machine or rail constituting [210] was put out of use.

3.3.10 Towards the northern edge of the trench, situated directly between timber [209] and foundation [210], was deposit (212), which comprised fragments of clinker, brick and timber cemented together within a slag-rich matrix. This deposit was 0.1m in thickness, and although it ran beyond the northern limit of the trench and underneath concrete [213] to the west, it was seen to cover an area measuring at least 2.1m by 1.1m. This deposit was situated directly above concrete [206], while it also abutted the northern edge of fill (211). The relationship between fills (212) and (211) served as an indication that the former was deposited after the latter had infilled foundation [210]. In terms of function, deposit (212) has been interpreted as a possible working surface, on top of which the operations of the plate rolling mill, for a certain time at least, were conducted. It can also be inferred that these operations had no connection with foundation [210], which had been put out of use by the time that (212) was deposited.

3.3.11 Both surfaces [206] and (212) were seen to run eastward beneath a later floor surface [213], and its composition was more or less identical to that of [206]. During the demolition of the site, concrete [213] was removed, revealing the older concrete floor [206] beneath it. This newer concrete floor measured 0.12m in depth, while its visible extent measured 1.9m in length by 1m in width, before running beyond the southern limit of the trench. Directly abutting concrete [213] to the northeast was an additional concrete floor, numbered [214], which was deposited in order to replace [213], during a time after [213] was partly demolished. The depth of concrete [214] was not ascertained as the juncture between [214] and [213] was viewed only in plan and not

in section. Stratigraphically, concrete [214] represented the latest floor surface discovered within the confines of the trench. In composition, concrete [214] was again fine in texture, yet buff in colour. Set within concrete [214], at a position 1.9m east of the eastern limit of concrete [213], was liner foundation [215]. This foundation comprised concrete of a slightly coarser texture than that of [214], which had been poured into a void formed presumably by shutters during the pouring of [214]. This meant that the concrete constituting foundation [215] was poured after concrete [214] had set. Alternatively, it is also possible that the concrete constituting foundation [215] was set in place first before concrete [214] was poured around it (after it had set). In total, foundation [215] measured 1.6m long x 0.39m wide. The true depth of foundation [215] could not be established, although [215] was seen to extend beyond the limit of [214] at a height of 0.06m. Foundation [215] was, furthermore, set in place with a NW/SE orientation. Set directly into the concrete of [215] were a pair of RSJs. The westernmost RSJ is numbered [216], while the easternmost is numbered [217]. The flanges of both RSJs were in parallel alignment with the longitudinal edges of foundation [215]. Both RSJs were also identical in size, measuring 0.24m long x 0.16m wide. These RSJs were cut during the demolition of the site, meaning that only their bases survived. With reference to their stratigraphic relationship with foundation [215], these RSJs were erected prior to the pouring of the concrete constituting [215].

3.3.12 Overall, foundation [215] has been interpreted here as the base for a machine or a feature associated with a machine. Situated 0.75m north of foundation [215] was drip gully [218], which was again set directly into concrete [214]. In profile, this gully was concave in form and markedly shallow, measuring no more than 0.03m in depth. In plan, drip gully [218] was 0.11m in width, and it extended for 4.8m in a NW/SE direction, while a pair of returns were observed running in a northward direction from its north-western and south-eastern edges, both at a 90-degree angle, beyond the northernmost limits of the trench. This meant that drip gully [218] was either square or rectangular in form. This feature has been interpreted as a drip gully primarily due its markedly shallow and narrow form, but also because it enclosed a small series of additional features that together once comprised a machine base. When this machine was in operation, therefore, drip gully [218] would have collected excess or waste oil (or other such fluids) that derived from it. The features constitutive of this machine comprised linear foundations [219] and [220], as well as the remains of pins [221] and steel plate [222]. Linear foundations [219] and [220] were set directly into concrete [214] and were situated 0.3m from the southernmost and easternmost edges of drip gully [218] respectively. In terms of their construction, both foundations were similar to [215] further west, as they were formed of concrete poured into voids formed during the deposition of concrete [214], presumably via shuttering. However, as mentioned with regards to the construction of foundation [215], it remains possible that concrete [214] was poured around foundations [219] and [220] after they were set in place. Foundation [219] was oriented NW/SE, in parallel alignment to the southernmost edge of drip gully [218], before merging into foundation [220], which projected from it at a 90-degree angle in a NE/SW direction beyond the northernmost limit of the trench. Also discovered in association with foundation [220] was re-deposited natural (224), which abutted its eastern edge. This deposit comprised a mid-

yellowy brown silty clay, 0.2m deep, and was situated directly beneath demolition deposit (201). In the south-facing section it was also observed that this deposit ran towards the eastern edge of the trench. The precise stratigraphic relationship between foundations [219] and [220] could not be established, however it was apparent that they were set in place at different times, as a clear juncture between the two was observed, represented by a gap in the concrete constitutive of both foundations. As these foundations extended beneath the northernmost limit of the trench, the true length of neither could be ascertained, although [219] was seen to measure at least 2.7m in length while [220] measured at least 0.65m in length. In terms of width, both foundations measured 0.16m. The remains of pins [221] were set within the aforementioned juncture between foundations [219] and [220]. They numbered two in total, and their presence was ascertained via a pair of narrow holes penetrating the concrete of [219] and [220]. These pins were removed prior to excavation, possibly during the demolition of the site. Steel plate [222] was set directly within foundation [219], approximately 0.3m to the north of its southernmost edge. The plate was notably small in size, measuring 0.29m long by 0.02m wide by at least 0.03m deep. Positionally, the plate was set on edge, and a pair of nails penetrated it on its eastern and western sides, which were also of steel. These nails measured 0.06m in diameter at the head, were T-shaped in profile, and their function was to hold the steel plate in an upright position within the concrete of [219]. The precise function of pins [221] and plate [222] is not known, although they likely served as structural reinforcements to the foundations of a machine. This machine, which altogether comprises features [218]–[222], has been numbered [223].

3.3.13 Discussion

3.3.14 As indicated by the 1946 aerial photograph (Figures 23–24) as well as the 1939 and 1951 plans (Figures 14–15 and Figures 18–21) of the works, the eastern half of Trench 2 covered mostly the core of the Hafod plate rolling mill building. Two features in particular – [223] and [215] – indicate the presence of machinery within the confines of the building. Although not fully uncovered, machine base [223] was rectangular or square in form and was either constructed with a NW/SE or NE/SW orientation. The 1939 plan of the works (Figures 13–14) indicates that [223] formed the southernmost corner of a broadly C-shaped machine, which represents the shears. The shears were used for cutting sections of rolled copper into individual plates. According to this plan, the shears were positioned immediately to the southwest of the plate flattening machine, parts of which were uncovered in Trench 5. However, in considering its position immediately in line with the shears, it may be suggested that sections of copper were transported from the plate flattening machine to the shears via the aid of gantry crane. The position of the gantry crane may also suggest that it was also used for removing copper plates from the shears after being cut to shape. Foundation [215] is slightly more difficult to interpret, although as suggested by Plate 86, which is a 20th century photograph of the processing line within the Hafod Plate Mill, it may have held an upright support for the gantry crane within this area. Both gantry crane and steel supports are visible in the photograph.

3.3.15 Features and Deposits at East End of Trench (Figures 1–2, 4 and 8; Plates 26–29)

3.3.16 Concrete [214] terminated approximately 2.8m west of the eastern limit of the trench. It was at this point that concrete [214] had been demolished, presumably during the demolition of the site as a whole, and a series of features and deposits were uncovered beneath. The lowermost of these – limecrete [229] – was situated immediately beyond the surviving limit of concrete [214] and was only partially observed. This limecrete was buff in colour and fairly friable in texture, and it contained frequent ash/coal inclusions throughout, as well as occasional patches of unslaked lime, white in colour. The extent of this deposit could not be ascertained, and neither could its function. Situated directly above limecrete [229] was concrete [226], which was very coarse and texture, measuring 0.1m in depth. Overlying limecrete [229] was an additional deposit of concrete, numbered [225], which was almost identical in texture and measuring 0.11m in depth. Both concrete deposits [225] and [226] appeared to represent floor surfaces or sub-bases that pre-dated the deposition of concrete [214] and were possibly contemporary with, or even the same as, concrete deposit [203] towards the opposite end of the trench. Within the south-facing section of the trench concrete [225] was seen to underlie slag deposit (227), which contained frequent sandstone fragments throughout. This deposit was red in colour, measured 0.04m in depth, and abutted the eastern edge of concrete [214], at the point at which it was demolished. Above deposit (227) was an additional deposit of industrial waste, numbered (228), which comprised black colliery waste with frequent fragments of green slag throughout. This deposit measured 0.05m in depth. Directly above deposit (228) was re-deposited natural (224), which was detailed above.

3.3.17 Discussion

3.3.18 The most notable deposit encountered at the eastern end of Trench 2 was limecrete [229], as it may have represented a structural component associated with the Hafod Hammer House, possibly constructed in 1819, that was demolished prior to the erection of the later plate rolling mill around 1910. The position of this Hammer House in relation to Trench 2 is suggested in Figures 11–12, which comprises a speculative plan of the works by Hughes. Neither the extent nor form of this deposit was ascertained during the excavation of Trench 2 and it is therefore impossible to determine which part of the Hammer House it constituted, if indeed it did constitute part of this building in the first place (it must be remembered that the Hughes plan is, after all, speculative). Yet in texture and appearance, this limecrete deposit appeared to pre-date 1910, and 19th century in date. The remainder of the deposits detailed above were either associated with the demolition of the plate rolling mill or constituted concrete foundations underlying its ground floor.

3.4 Trench 3

3.4.1 Trench 3 was NE/SW aligned and was positioned 2.5m to the east of Trench 1. The trench was, furthermore, positioned 1.9m from the south-western perimeter of the Musgrave Engine House and Rolls Scheduled Monument (SMGm483). In total, the trench measured 14.7m in length x 2.4m in width. The height at the top of the trench was recorded at 7.04mOD at its south-western end and 7.19mOD at its north-eastern. The height at the base of the trench varied. Towards the south-western end of the

trench, where concrete floor [302] was uncovered, the base height was recorded at 6.8mOD. Towards the centre of the trench, the base height was recorded at 6.15mOD. Finally, towards the north-eastern end of the trench, where annealing furnace [318] was uncovered, the base height was recorded at 6.5mOD. In total, the area covered by Trench 3 was 31.4m^2. The average depth of excavation was 0.45m.

3.4.2 **Stratigraphic Evidence**

3.4.3 The archaeological features and deposits uncovered within Trench 3 were associated with the core of the Hafod plate rolling mill. Broadly, the features and deposits uncovered within Trench 3 can be divided into three sections – the concrete floor of the plate rolling mill, situated towards the south-western end of the trench; the features underlying the plate rolling mill, which were concentrated towards the centre of the trench, which may include the remains of a quenching pool; and an annealing furnace, situated towards the north-eastern end of the trench. Apart from where specified otherwise, all archaeological features uncovered within Trench 3 directly underlay demolition deposit (301), which comprised fragments of demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix. The depth of this deposit ranged from 0.2–0.4m.

3.4.4 Concrete Floor of Plate Rolling Mill (Figures 1–2, 5, 9 and 10 Plates 30–33)

3.4.5 The concrete floor of the plate rolling mill was represented by concrete [302], which was concentrated towards the south-western end of the trench. The extent of this concrete could not be determined, as it ran beyond the southernmost, easternmost and westernmost limits of the trench, although its visible dimensions were 4.1m x 1.9m. This concrete was very fine in texture, grey to buff in colour, and had very fine sandstone inclusions throughout. In terms of depth, concrete [302] measured 0.24m. At 4.1m beyond the south-western edge of the trench, concrete [302] terminated at a clearly definable edge. Rather than being a result of demolition, this edge was formed as the concrete was being poured and represented a deliberately defined limit to the concrete floor. Immediately below concrete [302] was industrial waste (329), which was black in colour and highly friable. This deposit was not bottomed and measured at least 0.5m in depth.

3.4.6 Discussion

3.4.7 As mentioned above, concrete [302] constituted the latest floor deposit of the Hafod plate rolling mill. The fact that this deposit ends abruptly is difficult to interpret, as none of the available plans indicate that a termination in the floor of the plate rolling mill existed in this location. Certainly, this termination was not caused during the demolition of the site, as it was perfectly sheer and was formed during the pouring of the concrete. However, it is possible that this termination in concrete [302] represented the southernmost edge of a large rectangular quenching pool, which is shown on the 1945 plan of the works (Figures 15–16). This possible quenching pool has been numbered [328]. Although the position of Trench 3 and the outline of the pool fail to marry perfectly within Figures 15–16, this remains the most plausible explanation as to the abrupt termination in [302]. This pool, which according to the 1945 plan measured approximately 8m long x 5m wide, is shown as being aligned in a

broadly E/W direction and is abutting the southernmost edge of the annealing furnace recorded at the north-eastern end of Trench 3.

3.4.8 An alternative hypothesis to the one detailed above could be that the quenching pool is situated marginally beyond the eastern edge of Trench 3, meaning that the termination in concrete [302] was a result of some other feature. This feature may have been a simple downward step in the floor of the plate rolling mill. This seems unlikely, however, as on the 1945 plan of the works (Figures 15–16), the pool is shown as immediately abutting the southern edge of the annealing furnace, which was uncovered further to the northeast. The only section of the furnace that is not being abutted by the pool is its south-eastern corner, yet as this corner was not discovered within Trench 3, it must be assumed that the section of furnace that was uncovered was situated to the east of this corner and therefore in line with the pool. Moreover, the gap between the southern and northern edge of the pool, which is approximately 5m on the 1945 plan, is roughly equivalent to the gap between the northern edge of concrete [302] and the southern edge of the annealing furnace.

3.4.9 Features Underlying Plate Rolling Mill and Possible Quenching Pool (Figures 1–2, 5, 9 and 10; Plates 34–39 and 44–46)

3.4.10 Approximately 3.5m beyond the north-eastern end of concrete [302] was water pipe [303], which ran in a N/S direction beyond both the eastern and western edges of the trench. This pipe was heavily corroded and was covered in a thick mixture of pitch and slag. This meant that precisely determining the material from which the pipe was formed was difficult, although it was ostensibly formed either of steel or cast iron. The exterior diameter of pipe [303] was approximately 0.18m. Towards the eastern edge of the trench, and abutting pipe [303] on its northern side, was concrete [304], which extended in a north-eastward direction for 3.8m. This concrete was concentrated wholly towards the northern edge of pipe [303], against which it was poured. The true width of concrete [304] was not determined as it extended beyond the eastern limit of the trench, although it measured at least 0.6m from east to west. In depth, this concrete measured 0.09m. The texture of this concrete was fairly coarse, and it had large fragments of sandstone throughout, and was light grey in colour. Rather than being sheer like the north-western edge of concrete [302], the western edge of concrete [304] was irregular, indicating that a large section of it had been removed by machine prior to excavation. Sandwiched between the angle formed by the juncture of pipe [303] and concrete [304] was an additional deposit of concrete, numbered [306]. This concrete was very coarse in texture, and it appeared that it was deposited against pipe [303] not only after concrete [304] had set, but also after it had been partly demolished. Concrete [306] was also found in a fairly ruinous state, and in terms of its surviving dimensions, it measured 0.6m long x 0.25m at its widest x 0.06m deep.

3.4.11 Below the western edge of pipe [303] were the possible remains of a flue or culvert, numbered [305]. The identification of this feature as a flue or culvert remains tentative at best. Upon excavation, it appeared as an archway comprising two courses of unfrogged, tapered bricks, orange and buff in colour, and bonded with greyish lime mortar. These bricks, on average, were 0.8m long x 0.2m wide x 0.1m thick. Although the span of the archway was not fully revealed, it was seen to measure at least 0.7m in width. The archway, furthermore, appeared to be aligned in a broadly N/S direction,

travelling beyond and beneath the westernmost limit of the trench. Yet further excavation down the sides of this archway failed to reveal any side walls – essential components in the identification of this feature as a flue or culvert. It remains possible further excavation of [305] would have revealed some evidence of side walling, although this, as it presently stands, seems unlikely. A plausible explanation for [305] is that it represented the remains of a demolished flue or culvert that was deposited as part of demolition layer (301). Alternatively, it may have been deposited as part of demolition material of 19th century date that pre-dates the construction of pipe [303], concrete [304] and [306], and furnace [318]. Both the bricks and mortar of [305] indicate that the original flue or culvert to which it belonged was 19th century in date.

3.4.12 On the north-eastern edge of concrete [304] was concrete lip [307]. The intersection between [304] and [307] indicated that the latter was poured on top of the former and was therefore a later addition. The composition of concrete [307] was identical to that of [304]. In plan, concrete [307] measured at least 0.5m^2, although it was seen to extend beyond the limit of the trench on its eastern edge. In depth, concrete [307] measured 0.1m. Towards their north-western edges both concrete [304] and [307] were seen to abut the south-western edge of wall [311], which ran in a broadly E/W direction through the centre of trench and beyond its eastern and western limits. The bricks from which this wall were made were unfrogged, red in colour and were bonded with a grey cement mortar. Some of these bricks were demonstrably re-used, as not only had they had been irregularly cut to fit the shape of the wall, but residues of an ashy lime mortar were also noted on them. The true depth of wall [311] could not be ascertained as it ran below the limit of excavation, although it was recorded as being at least 0.54m deep. This wall was also only partly uncovered as a thick deposit of pitch/tar (or other such hydrocarbon) was stuck to its south-facing side, numbered (312). This deposit was also extremely compacted in texture, meaning that its removal from wall [311] proved very difficult. It seems likely that pitch/tar (312) was deposited during the installation of pipe [303] for the purposes of waterproofing. It may also be argued that wall [311] was erected in association with pipe [303], perhaps in order to support it in place. The juncture between pipe [303] and wall [311] was not, however, observed, which was presumably located beyond the western limit of the trench.

3.4.13 Within the southeast- and northwest-facing section of the trench a series of deposits were observed that related to the demolition of the site. Within the southwest-facing section, the lowermost deposit, numbered (323), comprised a mixture of brick rubble and brick dust, red in colour, with occasional fragments of slag throughout. This deposit was not bottomed but measured at least 0.2m in depth. On its south-western edge, (323) was overlain by deposit (322), which comprised re-deposited natural (mid-yellowy brown silty clay with rounded sandstone fragments). Again, this deposit was not bottomed, but measured at least 0.25m in depth. Situated above both (323) and (323) was deposit (321), which comprised a thin band of clinker measuring 0.1m deep. A dense concentration of ceramic sherds were identified within this deposit, which comprised plain white and cream earthenware (some of which transfer-printed, some of which dipped), pearlware, biscuit-fired pieces and kiln furniture. Directly overlying (321) was deposit (320), which consisted of large fragments of demolition material, mostly masonry, in a matrix of grey lime mortar and gravel. This deposit measured 0.7m in depth. Overlying (320) on its south-western edge was deposit (319), which

also partly overlay (321). This deposit was more or less identical to (320) save for its frequent inclusion of brick rubble. In fact, this deposit comprised at least 50% brick. In depth, deposit (319) varied between 0.4–0.7m. Situated directly above deposits (319) and (320) was demolition deposit (301).

3.4.14 The lowermost deposit uncovered within the northwest-facing section was a layer of brick rubble and brick dust (325), not bottomed but measuring at least 0.3m deep, which may have been the same as deposit (323) in the opposite section. This was seen to overlie, on its south-western edge, a thick layer of clinker and slag, numbered (324), which was not bottomed but measured at least 0.5m in depth. This deposit also abutted deposit (329), situated below concrete floor [302]. This deposit was also penetrated by pipe [303], however a cut for this pipe was not observed. Directly above deposits (325) and (324) was demolition deposit (301), which was also seen to abut the north-eastern edge of concrete [302].

3.4.15 Discussion

3.4.16 All deposits and features detailed above were situated immediately below the level of the plate rolling mill's ground floor, as represented by concrete deposit [302]. In consideration of the 1945 plan of the works (Figures 16 and 17), it appears that concrete [304] originally formed the western edge of quenching pool [328]. Moreover, it seems likely that pipe [303] once fed water into this pool from the west. In turn, in considering its alignment, this pipe may have also been attached to the hot well and therefore the boilers of the Musgrave steam engine. In this respect, it may have been the case that the same hot water used to fill these boilers was also used to fill quenching pool [328] and other features.

3.4.17 Below, the ceramic assemblage collected from deposit (321) is discussed in detail These ceramics derived from a nearby production site known as the Cambrian Pottery, which was in operation between 1764–1870. The inclusion of biscuit-fired pieces and kiln furniture within the assemblage is a clear indication that it represented kiln waste. Below, it is also stated that all ceramic fragments within the assemblage were of late 18th or early 19th century in date. The presence of this assemblage in amongst modern demolition material within Trench 3 was likely a result of Cambrian Pottery waste material being moved to the site for the purposes of levelling it (during the 20th century).

3.4.18 Annealing Furnace (Figures 1–2 and 5; Plates 40–43 and 87–88)

3.4.19 Towards their north-eastern edges, both concrete deposits [304] and [307], as well as support wall [311], abutted the south-western edge of wall [309], which ran in a parallel E/W direction. This wall appeared to form the southernmost edge of an annealing furnace [318], the surviving elements of which comprise of a series of brick and stone structures [311-317]. Wall [309] was only partially observed but was seen to have been constructed from sandstone masonry, in the form of thin, laminated slabs. Only two pieces of masonry were visible, both of which formed the uppermost course of the wall. The depth of this wall could not be determined, although it may be assumed that it was as deep as support wall [311] abutting its south-western edge. In width, wall [309] measured approximately 0.34m, while in length it was seen to measure 1.85m before running under both the eastern and western edges of the

trench. Immediately above wall [309] were a pair of steel plates, numbered [310], both of which were positioned directly above the two visible stones of wall [309]. Indeed, the dimensions of these steel plates, which measured 0.4m x 0.3m in plan, matched those of the underlying masonry perfectly, indicating that they were manufactured (or at least cut) for the precise purpose of topping wall [311]. Functionally, steel plates [310] appeared to have been placed here in order to provide structural support to wall [311]. Running off wall [311] at a perpendicular angle in line with the length of the trench, was wall [308]. Stratigraphically, wall [311] was later than wall [308], as the formed abutted the latter. Wall [308] was composed of unfrogged refractory bricks, yellow and orange in colour, and bonded with a grey, ashy lime mortar with rare flecks of unslaked lime throughout. This wall was also formed of a header bond, two courses thick, with both rows of headers being in parallel alignment to one another. The depth of this wall was not determined, although it was seen to measure at least 1.42m in length x 0.6m in width before running under the eastern limit of the trench. Abutting the western edge of the wall [308] was wall [315], which ran parallel alignment to it. This wall measured 0.3m in width x approximately 1.8m in length, although heavy root disturbance towards its north-eastern edge, caused by tree growth within this area, truncated the wall on this side, therefore masking its precise form and extent. In composition, wall [315] was identical to wall [308], aside from the fact that it was irregularly coursed, comprising both headers and stretchers, while it also comprised irregularly cut bricks that were clearly re-used. At most, wall [315] was a single header in thickness. Wall [315] appeared to form a narrow partition between wall [308] and wall [314], which abutted the western edge of [315]. This wall, in plan, measured at least 1.7m x 0.9m, while in depth it measured approximately 0.5m. Compositionally it was identical to both walls [308] and [315], although it was several courses in thickness (at least four) and irregularly coursed. One of the refractory bricks within [314] was stamped with the label 'JONES / DARRAN NO 1 / RISCA'. This particular brick appeared to be a later addition to [314]. Towards the centre of wall [314] was [313], which appeared as a small structure measuring 0.47m^2 in plan, square in form, that projected slightly beyond the uppermost course of [314]. The stratigraphic relationship between [314] and [313] could not be precisely determined although, superficially, it appeared that [313] was inserted into the confines of [314] at a later date. This structure was formed of notably large, unfrogged refractory bricks, yellow and orange in colour, each measuring, on average, 0.23m long x 0.11m wide x 0.1m thick. Again, the mortar bonding both the bricks within [313] together, as well as those of [313] and [314], was a grey, ashy lime mortar. On the north-eastern edge of [314] a series of steps had been incorporated, numbered [326], stepping downwards towards this direction. Despite the heavy root damage sustained within the area it as observed that these steps numbered four in total and together measured 0.5m in depth. Each step was formed of a row of headers and were constructed from the same bricks and mortar as wall [314]. Again, due to root damage the relationship between [314] and [326] could not be precisely determined, although it appeared that the latter was keyed in the former, meaning that they were constructed contemporarily. A series of corresponding steps were also incorporated into the north-eastern edge of wall [308]. These steps have been numbered [316] and were identical in composition and dimensions to [326]. However, a key discrepancy lies in their relationship with wall [308], as these steps merely abutted, and were not

keyed into, this wall. In addition, steps [316] extended slightly further north-eastward than steps [326] and descended directly down onto surface [317] (see below). As previously stated both steps [326] and [316] descended down onto basal surface [317], which was composed of the same refractory bricks and the same mortar. Moreover, another 'JONES / DARRAN NO 1 / RISCA' labelled brick was observed within this surface, which again appeared to be a later addition. The bricks of surface [317] were irregularly coursed. The extent of this surface was not fully observed, although it was seen to measure at least 2.05 x 1.6m in plan. Situated within surface [317], towards its visible eastern end, was an extensive and discrete area of possible repair work, demarcated by a straight joint in brickwork running the entire visible length of [317]. This area of repair has been numbered [327] and comprised a series of bricks identical to those of surface [317]. In plan, [317] covered an area measuring at least 2m x 0.6m. Together, all structural features throughout this section formed part of annealing furnace [318], which covered an area measuring at least 4.7m x 1.8m in plan.

3.4.20 Although the individual structural elements associated with annealing furnace [318] are discussed in detail above, it is worth, for purposes of clarity, to summarise this account. Overall, the surviving elements of furnace [318] that were uncovered in Trench 3 comprised a side (southern) wall in conjunction with a basal floor to its north. However, as detailed above, this wall and floor was subdivided into a series of smaller structural elements. In summary, it seems that structures [308], [311], [313], [314] and [315] formed a southern side wall to the furnace, while [317] and [327] comprised the floor of the furnace. Furthermore, it seems that steps [316] and [326] formed the juncture in between the wall and floor. In simple terms, these smaller structural elements likely represented individual instances of repair work to the furnace. Indeed, the high temperatures obtained within the furnace would have inevitably caused structural damage, which in turn would have necessitated constant repair to its brickwork. The complexity of the historic repair work applied to furnace [318] is reflected in the account above.

3.4.21 Discussion

3.4.22 The annealing furnace detailed above is illustrated clearly within the 1945 plan of the works (Figures 15–16). This plan shows the furnace to be rectangular in form, measuring approximately 8.5m long x 5.5m wide, and is aligned in a broadly E/W direction. In accordance with this plan, the structural remains discovered at the northeast end of Trench 3 represented the westernmost end of this furnace. As was mentioned above, this furnace is shown on the 1945 plan as being abutted by a quenching pool, the remains of which were possibly uncovered immediately to the southwest. This information is also corroborated on the 1939 plan of the works (Figures 13–14), within which both the furnace and quenching pool are identical in size and form to those drawn on the 1945 plan. The mortar observed bonding the bricks of this furnace together, which is lime mortar rather than Portland cement, is entirely consistent with it being of roughly Edwardian date. It is therefore likely that the furnace was constructed contemporaneously with the Musgrave steam engine and the Hafod plate rolling mill within which it was situated, in 1910. Both the 1939 and 1945 plans of the works show that another annealing furnace was situated immediately to the northeast, which is shown as being identical in size and form, while

beyond this second furnace are another pair of annealing furnaces, which are far smaller in size. Plate 88, which is a 1971 photograph of one of the annealing furnaces within the Hafod Plate Mill, is able to aid greatly in the interpretation of furnace [318]. This photograph demonstrates that, in its complete form, the furnace would have comprised a central floor, on top of which sections of copper would have been heated, that was defined on each edge by a side wall. Running along the eastern edge of all of these furnaces, a series of live rolling tables is shown, which are attached to fixed rails, which is demonstrated in Plate 87. These rolling tables were mechanised and would have fed sections of copper to and fromm the annealing furnaces before being transferred to the quenching pool. As mentioned above, the rails for these live rolling tables are shown as ending in line with the quenching pool.

3.5 Trench 4

3.5.1 Trench 4 was broadly aligned E/W and was rectangular in form, measuring 3.9m in length x 1.9m in width. In terms of position, the trench was located towards the base of the retaining wall separating the study from Morfa Road to the west. The trench was also positioned 2.6m south of Trench 1. The height at the top of the trench was recorded at 7mOD, while the height at the base of the trench was recoded at 6.6mOD at its deepest (western) end. At this level, the water table was encountered, meaning that significant ingress occurred across the entirety of the trench. As a result, excavations were limited to this depth. Both the excavation and recording of the trench was intermittent, as it necessitated the periodic removal of water via machine. In total, the area covered by Trench 4 was 6.96m^2. The average depth of excavation was 0.4m.

3.5.2 **Stratigraphic Evidence (Figures 1–2 and 6)**

3.5.3 The archaeological features and deposits uncovered within Trench 4 were associated with drainage attached to the western wall of the Hafod plate rolling mill annex. All archaeological features uncovered within Trench 4 directly underlay demolition deposit (401), which comprised fragments of demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix. The depth of this deposit measured 0.4m.

3.5.4 In the south-western corner of the trench, wall [403] was revealed. The visible extent of this wall measured 0.4m long x 0.2m wide, although it ran beneath both the southernmost and westernmost limits of the trench. The wall was composed of unfrogged, red bricks, and only the uppermost course was visible, which comprised headers. Some of these bricks were highly degraded and possibly re-used. In orientation, the wall was aligned in a broadly E/W direction. The mortar bonding this wall together comprised a black, ashy lime mortar. Approximately 0.7m to the north of [403] was wall [403], which was identical in composition. Although walls [403] and [402] shared a broadly similar alignment, it was also evident that they were not perfectly parallel and were slightly offset from one another. In terms of its visible dimension, wall [402] measured 0.8m long x 0.2m wide, before running beneath the northern and western limits of the trench. Running in a NE/SW direction along the easternmost limit of the trench was drainage gully [404]. This gully in was identical in form and dimensions to [135] uncovered in Trench 1, while it also shared the same broad orientation. Gullies [404] and [135] are therefore likely to be one and the same

feature. Due to flooding issues, no further features or deposits were uncovered within the trench. The basal deposit comprised demolition layer (401), which was situated above and abutted the sides of walls [403] and [402] as well as gully [404].

3.5.5 Discussion

3.5.6 According to the 1946 aerial photograph of the area (Figures 23–24) as well as the 1939 and 1945 plan of the Hafod works (Figures 13–16), Trench 4 was situated towards the southern end of the Hafod plate rolling mill annex. More specifically, it is shown as transecting the western wall of the annex. This western wall was not observed within the trench, although the drainage channel running along its western edge was observed, as represented by feature [404]. Walls [403] and [402] are difficult to interpret definitively. Upon excavation, it was assumed that these walls formed the edges of a single manhole, although as their alignment is not quite parallel, this interpretation is unlikely. The level at which these walls were uncovered as well as their 20th century date would indicate that they were in some way associated with drain [404], although this remains inconclusive. The 1946 aerial photograph indicates the presence within Trench 4 of a small projecting compartment, which extends approximately 1m westward from the line of the annex wall. This compartment is apparently associated with another two compartments situated further to the northeast, which again project westward from the annex wall. It may be that wall [403] formed the northeast wall of the compartment, although without further excavation this idea remains tentative. The function of this compartment is unknown and is not indicated on any of the available plans of the works.

3.5.7 **Trench 5**

3.5.8 Trench 5 was irregular in form and covered a total area of 37.1m^2. In terms of its position, the trench was situated approximately 4.3m north of Trench 2 and 4.4m southeast of Trench 3. Furthermore, the northernmost (lateral) edge of Trench 6 was positioned in parallel alignment with the southernmost edge of Trench 5, with the two trenches eventually being joined up at this point for the purposes of obtaining a clearer view of the archaeological features uncovered within, which pertained to the interior of the Hafod plate rolling mill. The height at the top of the southern end of the trench was recorded at a 7.49mOD, while the height at its northern end was recorded at 7.3mOD. The height at the base of the trench was recorded at 7mOD at its deepest. The average depth of excavation was 0.4m.

3.5.9 **Stratigraphic Evidence (Figures 1–2 and 7; Plates 47–58)**

3.5.10 The archaeological features and deposits uncovered within Trench 5 were associated with the interior of the Hafod plate rolling mill. All archaeological features uncovered within Trench 5 directly underlay demolition deposit (501), which comprised fragments of demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix. The depth of this deposit between 0.1–0.33m.

3.5.11 Running in a NE/SW direction through the north-eastern corner of Trench 5 was a steel rail [510]. The depth of this rail was not determined and neither was its profile. However, its upper surface was mostly flat, with only slight traces of concavity, and did not incorporated flanges. The width of this rail was 0.13m while its visible length was 2.25m, before running beneath the limits of the trench to the northeast and

southwest. It was observed that rail [510] was set within concrete floor [503], which was fine in texture and contained fine gravel inclusions throughout. The surface of concrete [503] was visibly scarred by scuffs and scrapes, presumably caused by the movement of machinery within the plate rolling mill, although these may have also been inflicted during the demolition of the site. The full extent of this concrete was not ascertained, although it covered almost the entirety of the trench, measuring at least 8.9m x 4.2m. Referring to the relationship between concrete [503] and rail [510], it appeared that the latter was set in place prior to the pouring of the former around it. Immediately overlying concrete [503] was scree deposit (502), which consisted of a mixture of crushed stone and concrete fragments. This deposit was highly fragmented and survived only in patches. In depth it also varied and measured between 0.02–0.1m. This deposit may have acted as an additional working surface within the plate rolling mill, yet it was confined to the area occupied by concrete [503] alone. Also set within concrete [503] was manhole [509], which was situated approximately 0.15m to the west of rail [510]. This manhole was uncovered in a highly ruinous state and none of the materials from which it was constructed appeared to survive. Instead, it survived as a rectangular void within concrete [503], with steel plates defining its southern and western edges. In plan, this manhole covered an area measuring 0.68m in length x 0.4m in width. The fill of this manhole comprised demolition deposit (501) and was not bottomed.

3.5.12 Approximately 0.9m from the south-western edge manhole [509] and 0.7m from the visible south-western edge of rail [510], a downward step, or split-level, was observed in concrete surface [503]. The depth of this step was approximately 0.15m. In alignment, this step ran in a NW/SE direction beyond both the eastern and westernmost limits of the trench. Around 1.6m beyond the south-western edge of this step was manhole [508], which was set into concrete [503] and rectangular in form, covering an area measuring 0.74m long x 0.41m wide. The depth of this manhole was 0.39m. This manhole survived in a markedly good condition. The side walls of this manhole were composed of both brick and concrete slabs. The brick elements of the manhole extended from the base to 0.2m up the side walls. These bricks were red in colour and comprised a stretcher bond of five courses in height. These bricks were also bonded with grey cement mortar. Above these bricks was a deposit of shuttered concrete that formed the rectangular footprint of the manhole. This concrete was thin, measuring 0.03m in thickness. This concrete, moreover, extended 0.19m above the upper courses of brickwork below it. Stratigraphically, both the bricks and concrete of manhole [508] were set in place prior to the pouring of concrete [503] around them. A shallow 0.12m wide gallery, formed via the juncture between this upper concrete deposit and concrete floor [503], was incorporated, which would have held a cover in place. This cover did not survive *in-situ*. The remains of a steel pipe were observed at the base of the manhole, measuring approximately 0.18m in diameter, that ran into the base of the manhole from a south-westward direction. Around 2.25m beyond the south-eastern corner of manhole [508] was RSJ [507], which was again set into, and pre-dating the pouring of, concrete [503]. The flanges of this RSJ were aligned in an approximately NW/SE direction. The total area covered by this RSJ was 0.74m x 0.41m. Only the base of the RSJ survived *in situ*. Immediately 1.4m northwest of RSJ [507] were the remains of an additional RSJ, numbered [511],

which had again been cut off at the base. This RSJ was aligned parallel with [507]. In plan, this RSJ covered an area measuring 0.13m x 0.08m and was therefore of significantly smaller size than [507]. Like [507], the setting of tis RSJ in place pre-dated the pouring of concrete [503]. Approximately, 0.85m to the southwest of RSJ [507] was manhole [506]. This manhole was identical in construction and form to manhole [508] further north but covered an area measuring 0.66m in length x 0.42m in width x 0.4m deep. The stratigraphic relationship between manholes [506] and [508] and concrete [503] was also identical. Manhole [506] was, however, aligned in a different direction to [508] and had a broadly E/W orientation. In contrast to manhole [508], there was no visible pipework in the base of the manhole.

3.5.13 Approximately 2.45m southwest of manhole [508] another downward step within concrete floor [503] was observed, measuring between 0.1–0.15m in depth. This split level formed the easternmost edge of machine base [504], the extent of which was not fully determined. This machine base was moulded directly into concrete [503], presumably via the aid of shutters, which did not survive *in situ*. In plan, this machine base appeared broadly L-shaped and comprised an upper, NE/SW aligned bay measuring at least 3m long x 0.8m wide with an additional sunken bay running off its south-western edge at a perpendicular angle, measuring at least 2.9m long x 0.7m wide. The split level between these bays demarcated the division between the machine base proper and the electric cabling feeding into it, with the former occupying the upper level and the latter occupying the lower. The difference in height between these two bays was approximately 0.15m. The lower bay, as well as the electric cables it once contained, was presumably subterranean, as indicated by the fact that its original cover, represented by an extension of concrete [503] was smashed upon during the demolition of the site, thus revealing the lower bay of [504]. Within the upper bay of machine base [504] was a pair of substantial, vertically set steel pins, situated 0.4m apart and aligned in a NW/SE direction. These pins were situated towards the southernmost edge of the upper bay. Originally, these pins would have held a machine in place. Within the southwest-facing section of the lower bay the heavily disturbed remains of an armoured electric cable were discovered, numbered [505], which appeared to run in broadly NE/SW direction from within or beneath concrete [503]. There was, moreover, a narrow, linear notch let into the north-eastern corner of the lower bay, measuring 0.05m in width x 0.42m in length x 0.07m in depth. This notch facilitated the entry of another electric cable, which would have entered the lower bay of machine base [504] from an eastward direction. The electric cable itself did not survive *in-situ*.

3.5.14 <u>Discussion</u>

3.5.15 Both the 1939 and 1945 plans of the Hafod works (Figures 14–15 and Figures 18–21) indicate that Trench 5 was positioned directly within the interior of the Hafod plate rolling mill. This is also corroborated by the information provided by the 1946 aerial photograph of the works (Figures 23–24). Within the context of the activities conducted on the interior of the mill, the most notable feature recorded within Trench 5 was machine base [504]. This machine base was sunk into the floor of the mill. The 1939 plan of the works (Figure 13–14) demonstrates the presence of a machine within the area it is the 1945 plan (Figures 15–16) that illustrates this machine most clearly. On this plan, the machine covers a relatively large area of approximately 6m^2 and is

labelled as the 'plate flattening machine'. This machine was responsible for removing the minute defects on a section of pre-rolled copper in order ensure that its surfaces was as flat and even as possible before being sheared to shape. As discussed above, the shears were uncovered within Trench 2. The only remains associated with this machine that were encountered within Trench 5 were its foundations. Rail [510] is also of interest, as it appears to have formed the southernmost limit of the live rolling tables indicated on the 1939 and 1945 plans of the works (Figures 14–15 and Figures 18–21). The remainder of the features uncovered within Trench 5 were associated with drainage.

3.6 Trench 6

1.1.1 Trench 6 was broadly E/W aligned and was positioned parallel to, and 2m north of, Trench 2. Initially, the trench was linear in form, measuring 13.8m in length x 1.9m in width. However, the trench was extended slightly northward to combine with Trench 5. This was accomplished for the purposes of obtaining a clearer view of the archaeological features uncovered within both trenches, which pertained to the interior of the Hafod plate rolling mill. The height at the top of the western end of the trench was recorded at 7.23mOD, while the height at its eastern end was recorded at 7.36mOD. The height at the base of the trench varied. At its western end, the base height was recorded at around 6.5mOD at its deepest, while towards its eastern end, where the floor of the Morfa plate rolling mill was uncovered, the base height was recorded at 7mOD. The deepest point of the trench, represented by the interior of machine base [617] towards its east end, was recorded 6.46mOD. In total, the area covered by Trench 6 was 27.63m^2. The average depth of excavation was 0.5m.

3.6.1 **Stratigraphic Evidence**

3.6.2 The archaeological features and deposits uncovered within Trench 6 were associated with the core of the Hafod plate rolling mill. Broadly, the features and deposits uncovered within Trench 6 can be divided into two sections – the features and deposits underlying the mill's annex, confined to the western half of the trench; and the interior of the mill proper, confined to the eastern half of the trench. Apart from where specified otherwise, all archaeological features uncovered within Trench 6 directly underlay demolition deposit (601), which comprised fragments of demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix. The depth of this deposit ranged from 0.1–0.3m.

3.6.3 <u>Features and Deposits Underlying the Hafod Plate Rolling Mill Annex (Figures 1–2, 7 and 11; Plates 59–64)</u>

3.6.4 The lowermost feature uncovered within the western half of the trench was structural deposit [612], which was only partially observed at the base of the trench (0.9m below its top) at the limit of excavation. This feature comprised a short stretch of sandstone masonry bonded with a buff or yellow coloured lime mortar with frequent flecks of unslaked lime throughout. This feature, therefore, was possibly a wall running in a broadly N/S direction. The blocks of masonry comprising this wall were rectangular in profile. Only 0.15m of this wall were uncovered and the remainder of it was situated below the base of the trench. Penetrating the masonry of this feature was an apparent wall anchor and anchor plate, with the latter forming the east-facing façade of the

wall. Both anchor and plate were formed of wrought iron. However, the plate was situated approximately 0.25m beyond the eastern face of the wall. This meant that, either the wall face was heavily disturbed prior to excavation, causing the anchor to protrude beyond its original position, or that this feature was not in fact a wall anchor and was instead some other type of support. Although little could be said of possible wall [612], in consideration of its early date, the notion must be considered that it once formed part of the Hammer House that once inhabited this area during the 19th century.

3.6.5 Abutting the eastern edge of possible wall [612] was re-deposited natural (611), which comprised a mid-yellowy brown silty clay with frequent rounded sandstone inclusions. This deposit covered an area measuring approximately 1.5m x 0.5m and extended beyond the northernmost and southernmost limits of the trench. This deposit was ostensibly concentrated to the eastern edge of possible wall [612], although as it was not fully excavated, or indeed uncovered, this was not proven conclusively. To the east of possible wall [612], and overlying re-deposited natural (611), was demolition deposit (605), which comprised a dark brown loam with brick fragments throughout. The depth of this deposit ranged between 0.1m–0.4m. Directly overlying possible wall [612]) was concrete [606], which probably represented one of the floor surfaces of the plate rolling mill annex. This concrete appeared as a slab penetrating the south-facing section, on the northern edge of the trench. It also ran beyond the limit of the trench to the east. Compositionally, concrete [606] was fine in texture and was apparently formed *in-situ*. The eastern edge of this concrete formed a sheer edge, approximately in line with the eastern face of possible wall [612]. In depth, concrete [606] measured 0.34m.

3.6.6 Towards the opposite (southern) edge of the trench, was additional concrete slab [607], which was concentrated to the small area above wall [612] at the point at which the possible anchor plate was situated. Concrete slabs [607] and [606] likely formed the same floor surface and the gap between the two was formed during the demolition of the site. Although heavily disturbed, in depth concrete [606] measured approximately 0.3m. Overlying both concrete [606] and [607] was a thin deposit of scree, numbered (603), which comprised a mixture of crushed gravel and concrete fragments. In depth, this deposit measured approximately 0.1m, although it was very disturbed and exhibited only a patchy distribution. Immediately underlying demolition deposit (601) but overlying scree deposit (603) was organic horizon (602), which represented an historic turf layer. This layer was situated approximately 0.3m below the present ground surface and was, on average, 0.3m deep. In composition, deposit (602) comprised dark brown or black silty clay with frequent, small stone chippings throughout. The historic turf that deposit (602) represented accumulated after the demolition of the site, yet before the deposition of (601). As well as overlying scree (603), this deposit was also seen to partly overly demolition deposit (605) further east. Towards the eastern edge of (603) and (602) was an additional historic topsoil deposit (604), 0.15m thick, which survived only partially in section. Approximately 2.7m east of possible wall [612], and underlying scree deposit (603), a drainage channel, numbered [608], was recorded within the south-facing section, which cut directly through demolition deposit (605). This drainage channel was 0.5m wide x 0.4m deep. In form, it had a concave base and relatively steep sides. In total, the channel

contained two fills – a lower, basal fill, numbered (609) and an upper fill, numbered (610). Fill (609) comprised light grey and yellow sand and was 0.08m deep. Fill (610 comprised fine gravel in a dark grey silty clay matrix, 0.3m deep. Also observed underlying deposit (605) were the heavily disturbed remains of armoured electric cable [613], which ran in a broadly N/S direction beyond the northern limit of the trench. It is likely that this cable ran into the lower bay of machine base [504].

3.6.7 Discussion

3.6.8 Above, the 1819 Hafod Hammer House was discussed, which was demolished prior to the erection of the later 1910 plate rolling mill. Wall [612] may represent the partial remains of this Hammer House, as its form and mortar are suggestive of it being 19th century in date. Figures 20–21, which date to at least 1926, show the partly erased outlines of both the old rolling mills (Nos 1 and 2) and the Hammer House. Within Figures 11–12, wall [612] appears almost perfectly in line with the eastern wall of the Hammer House. The remainder of the features and deposits uncovered within the western half of Trench 6 were associated either with the flooring of the plate rolling mill's annex or with its later demolition.

3.6.9 Interior of Hafod Plate Rolling Mill (Figures 1–2 and 7; Plates 65–72)

3.6.10 Immediately beyond the visible eastern edge of demolition deposit (605) were the remains of the plate rolling mill floor, as represented by concrete [614]. The westernmost edge of this concrete was created when [614] was demolished. This floor, therefore, extended significantly further to the west in its original, intact state. The depth of this surface was 0.15m. This surface was possibly associated with, or equivalent to, concrete slabs [606] and [607] on the other side of the trench to the west, meaning that, prior to the demolition of the site, all three of this concrete deposited formed the same surface. In total, surface [614] covered an area measuring at least 3.5m x 0.8m, although its true extent was not observed. Directly overlying surface [614] was an additional concrete surface, numbered [619]. In terms of the visible area it covered, this concrete measured at least 7.8m x 2.1m and was 0.2m in depth. In considering the fact that surface [619] originally formed the floor of the plate rolling mill within which it was contained, it became clear that this section of concrete [614] was a subterranean surface and was not meant to be seen. This is supported by the presence of a linear notch set into the eastern edge of [619], through which an electric cable would have been fed and which would have ran beneath primary floor deposit [619] yet above surface [614]. In this sense, this surface [614] is comparable to the surface of the sunken bay within machine base [504] in Trench 5 to the north. Immediately north of [surface] [614] was an additional concrete surface, numbered [620]. This surface was the same as [503], as uncovered within Trench 5 – a fact firmly established by the merging of Trenches 5 and 6. Stratigraphically, surface [620] was situated at a higher level than [614], which again supports the notion that the latter was intended as a subterranean surface. Both surfaces, however, were separated by a linear stretch of concrete [615] measuring 3.2m in length, which ran in an E/W direction. This stretch of concrete was also 0.15m in width, and in terms of depth it varied from being perfectly level with surface [614] at its westernmost end to being raised 0.15m above the line of [614] at its westernmost. This concrete feature [615] has been interpreted as possibly forming part of a machine base. Alternatively, this

feature may have instead been associated with a machine base and may have constituted, for example, formal shuttering or a container for waste liquids (such as oil). Compositionally and texturally, the concrete [615] was identical to that of [614]. The precise stratigraphic relationships between concrete deposits [614], [615] and [620] proved difficult to determine. Yet in consideration of the split level that existed between [614] and [615], it would seem most feasible that [620] was deposited first before [614] and [615] were poured against its southern and northern edges. In association with [615] were the remains of vertically set RSJ [616], which covered an area measuring 0.14m^2. This RSJ was set directly within concrete [614]. Towards the western side of [615] were the remains of a sunken bay [621]. This bay, in form, was incorporated directly into concrete floor [614]. Its visible dimensions were 0.34m wide x 0.9m long, before running beneath the edge of excavation. Moreover, this bay was seen to be filled with rubble deposit [601]. In considering its position and alignment, this bay was likely the same as [504] in Trench 5 and may therefore be interpreted as a machine base. Approximately 0.2m to the southwest of [621] was foundation [622], which again represented a bay set directly into concrete [614] that was infilled with rubble [601]. However, this feature was uncovered in a highly disturbed state and neither its true form nor function could be ascertained. In form, [622] was amorphously shaped, although its eastern, southern and northern edges were seen to be in perpendicular alignment, suggesting that it was originally square or rectangular in profile. It is likely that this feature either comprised a machine base associated with [621] or a manhole. In terms of its surviving dimensions, feature [622] covered an area measuring approximately 0.26m^2.

3.6.11 Towards the eastern edge of concrete [619] was a continuation of concrete surface [620], which was seen to run beneath [619]. This stretch of surface [620] ran beneath the limits of excavation to the north and south, although it was also seen to extend 1m eastward before abruptly terminating at feature [617]. The process of precisely determining the function of this feature was difficult, as only a small section of it was revealed during excavation. Yet the 1945 ICI plan of the works (Figure 17–18) demonstrates that a quenching bosh once occupied this position. It is possible that [617] represented this quenching bosh, yet it is also possible that it represented a feature associated with the bosh. Feature [617] was rectangular in form and measured 0.6m wide. The precise length of this feature was not ascertained as, although its southern edge was uncovered, it nonetheless ran in a northward direction beyond the limit of excavation. This feature, therefore, measured anywhere over 1.5m in length. The precise depth of this feature could likewise not be ascertained as it was not fully excavated, although it was recorded as being at least 0.48m deep. Compositionally, feature [617] comprised a simple gap in concrete surface [620], and was likely formed via the placement of shuttering, which demarcated its edges during the pouring of the concrete that constituted [620]. Incorporated into its southern end were a pair of notches, both of which extended 0.1m beyond the south-eastern and south-western corners of the feature. These notches would have facilitated the vertical movement of some form of implement, allowing it to enter and exit the feature. The bulk fill of feature [617], numbered [618], comprised a mid-reddish brown silty clay with frequent demolition material throughout, including brick and masonry fragments as well as sections of plastic sheeting. This fill was also seen to contain a bag of cement-

based sealant, possibly grout, which had been cut open, meaning its contents formed a heavily compacted layer beginning 0.48m below the top of the feature. It was due to this hardened layer of sealant that the full excavation of feature [617] proved impossible. Beyond the eastern limit of bosh [617], concrete surface [620] continued for 1.2m, before extending beyond the limit of excavation.

3.6.12 Discussion

3.6.13 The features and deposit uncovered within the eastern half of Trench 6 were demonstrably associated with the operations conducted within the interior of the Hafod plate rolling mill. RSJ [616] appears to have marked the juncture between the mill's annex and the mill proper. This serves as an indication that, much like the western wall of the annex, the wall separating the mill proper and the annex was again formed mostly of steel members rather than brick or masonry walling. Machine base [615] represents the remains of the shears, which is shown in the 1939 plan of the Hafod works (Figures 13–14) as being positioned on the southern end of the mill. In this respect, base [615] is broadly equivalent to base [215] in Trench 2, which is also interpreted as having formed the southern part of the shears. More specifically, foundation [615] appears to have formed the northern end of the shears, with the southward return partially detected on its southern end corresponding almost exactly with the form of the shears in the 1939 plan. Finally, it seems likely that feature [617] was originally attached to or was at least associated with a quenching bosh. As demonstrated in Figure 17–18, the form of this feature is in slight discordance with the bosh itself, as where the former is narrow in form, the latter is wide in form. In considering the notches incorporated into the southern edge of feature [617], it is possible that it represented some form of machine pit used for lowering and raising sections of copper in and out of the quenching bosh.

3.7 **Finds** (by Joyce Compton)

3.7.1 **Introduction and Methodology**

3.7.2 A small group of finds has been recovered from recent work; these have been recorded by count and weight, in grams, by context and type, and the data entered onto Excel spreadsheets for ease of manipulation. The spreadsheets form part of the archive. The finds are described by category below.

3.7.3 **Modern Glass**

3.7.4 Context (001) produced a colourless jar or bottle base, which is milled along the external edge. The jar maker's initials and mould numbers are embossed under the base. There is a grey deposit internally and over the broken edges.

3.7.5 **Pottery**

3.7.6 This component forms the bulk of the assemblage amounting to 45 sherds, weighing 309g. In addition, there are eight sherds (38g) which are biscuit-fired, along with items of kiln furniture and possible clay off-cuts. Both the pottery and the kiln waste are in relatively good condition, although there is much staining, either dark grey/black or iron-coloured.

3.7.7 Because of the presence of recognisable kiln waste, all of the ceramics are treated as such and have been divided into type, accordingly. The divisions are plain white

earthenwares, decorated white earthenwares and kiln furniture. The last two categories have been further sub-divided for the purposes of this report.

3.7.8 **Plain White Earthenware**

3.7.9 There are sixteen sherds (weight 134g) of undecorated white and cream earthenwares, representing 45% by weight of the pottery from context (321) (Plate 73). White and cream-coloured sherds are present in roughly equal amounts and there is a variety of vessel types. Plate sherds are perhaps the most numerous. The cream-coloured pottery is not the deep cream of the earliest vessels, which were first produced in the mid-18th century. A whiter body was created by adding calcined flints, among other ingredients, to the raw clay and this became common practice by the end of the 18th century (Copeland 2003, 41).

3.7.10 **Decorated Creamware**

3.7.11 Two different lower wall sherds are present (from context 321) (Plate 74). Both are decorated with similar swirled marbled designs in cream, pale orange-brown and dark brown, and known as dip ware. A dip-ware tankard, dated c.1800, is described in Armistead and Grant-Davidson (1968, 12, cat.no.15). See also Nance (1942, 158, pl. LXVI C) for the same tankard, dated here to the period 1824-50. Sherds with similar decoration, excavated from the Cambrian Pottery refuse tips, are shown on the same plate (pl. LXVI A & B).

3.7.12 **Decorated White Earthenware**

3.7.13 There are three pearlware plate rim sherds with feather or shell edging, which have been over-painted in cobalt blue along the rim edge (from context 321) (Plate 75). Plates with similar edging from the Cambrian Pottery, and dated 1788, are shown in Gray (2003, pl. 2.22-2.24). Pearlware is named for the blue tinge imparted by drops of cobalt added to the glaze.

3.7.14 **Hand-painted Decoration**

3.7.15 Sherds with different schemes of hand-painting are shown in Plates 76–77 (from context 321). The first is a distinctive line-and-dot design painted along the rim edges. Unfortunately, the decoration on the body is only partly visible. The second shows a part of a two-colour floral border. It has been noted that the edges of plates were often painted in ochre, chocolate and sometimes orange (Armistead and Grant-Davidson 1968, 8), as in this example. Pearlware sherds with near-identical designs, found close to the Cambrian Pottery, are illustrated by Gray (2005, pl. 3.31), and are dated 1800-1815.

3.7.16 **Transfer-printed Ware**

3.7.17 There are 24 sherds (103g) of cobalt-blue transfer-printed wares (from context 321). This category also includes undecorated sherds which have a blue tinge, since these may derive from printed vessels (Plates 78–79). Unfortunately, the transfer-printed pottery is the most fragmentary (average sherd weight 4.3g) and it has not proved possible to tie-in any of the schemes of decoration with published examples.

3.7.18 **Biscuit Sherds**

3.7.19 Eight (38g) unglazed 'biscuit' sherds were recorded (Plate 80). These are the remains of vessels which apparently have not survived the first firing. Once pottery had been biscuit-fired, decoration could be applied before glazing and then vessels were fired again in a glost kiln, from which further breakages were likely.

3.7.20 **Kiln Furniture**

3.7.21 Three types of kiln supports are shown in Plates 81–83 (from context 321); firstly, glazed tripods or three-pin cockspurs, in two sizes, secondly, glazed plate supports and stilt fragments, and thirdly, unglazed stilts and curved fragments. Cockspurs and stilts were inserted between each vessel to keep them separated during the kiln-stacking process. Plate supports were used when plates were stacked on their rims end-on, each separated by a small hooked 'thimble'. These supports very often left a small scar under the rims of fired vessels. Copeland (2003, 51, pl. 3.20) demonstrates various methods used in stacking vessels in the kiln. Glazed supports were used in glost firings and unglazed for the biscuit stage (Chapman 2003, 183). The unglazed curved strips may be off-cuts of wadding-clay, used to form a seal when stacking saggars, or they could be fragments of setting rings used to support hollow wares in the kiln. These fragments are, unfortunately, too small for certain identification to type. Chapman (2003, pl. 10.3) illustrates the large quantity of unglazed setting-ring fragments found at Torksey, used in the manufacture of porcelain.

3.7.22 **Discussion**

3.7.23 The Pottery was set up in 1764 on the site of an old copper works on the Strand by iron founder William Coles of Cadoxton. Production started in 1767 and the output at first was mainly coarse red wares. When Coles died he left the pottery to his three sons, although output then was restricted due to a period of recession resulting from the American War of Independence (Gray 2003, 22). George Haynes joined the pottery in the late 1780s and was in partnership with John Coles by 1790. The partnership (trading as Coles and Haynes) extended the works, now named Cambrian Pottery, and began producing fine quality earthenware similar to that produced by Wedgwood.

3.7.24 William Dillwyn purchased a controlling interest in the pottery in 1801 on behalf of his son, Lewis Weston Dillwyn (Armistead and Grant-Davidson 1968, 8). Haynes was kept on as managing partner, and the firm was known as Haynes, Dillwyn & Co. Haynes withdrew from the partnership in 1810 and Dillwyn took on the Bevingtons as partners. The Pottery continued, intermittently, under Dillwyn's control and was signed over to Dillwyn's son in 1836. The Pottery passed to Evans and Glasson in 1850 and eventually closed in 1870 (Armistead and Grant-Davidson 1968, 10).

3.7.25 During the life of the Pottery, various name-stamps and marks were used, the first being an impressed 'Swansea' mark current from about 1803 (Gray 2005, 66). Artists and gilders used ciphers to denote their work, all painted under the base. Unfortunately, none of the sherds in the current collection are marked, so firm dating cannot be assigned. It seems likely, however, that a date bracket of 1785 to 1850 is possible, that is, from the start of Haynes' involvement until the handover of the Pottery to Evans and Glasson. It should perhaps also be noted that no sherds are gilded

and there is no hand-painting in the style of the various artists employed by Dillwyn, although there are probably too few sherds in the assemblage for this to be meaningful.

3.7.26 It is interesting that pottery waste from the Cambrian Pottery has been incorporated into a levelling layer at Hafod Morfa copper works. The Pottery was sold in 1870 and the site cleared to make way for a fuel works. Whether the waste was moved then or later, perhaps when the fuel works closed, is difficult to ascertain. Wherever the Cambrian Pottery waste dumps were located, they must have still been accessible during the first half of the 20th century, or sherd collections could not have been made by either Meager or Nance (Armistead and Grant-Davidson 1968, 12; Nance 1942, 158, fn.4).

4 Discussion and Conclusion

4.1.1 A total of six trenches were excavated across the study area (Trenches 1–6). Within Trench 1 the remains of the annex attached to the western edge of the Hafod plate rolling mill were encountered. These remains comprised the western wall of this annex, including drainage features attached to it, as well as a single, concrete bay that held the hot well and pumping chamber. This hot well was itself attached to the Musgrave steam engine further north, situated directly within the curtilage of the Musgrave Engine and Rolls (SMGm483). Within Trench 2, the interior of the annex and mill were encountered. Most notably, the trench included the remains of the shears. Moreover, towards the eastern end of the trench possible, structural remains associated with the 19th century Hafod Hammer House were encountered. Within Trench 3, the remains of an annealing furnace were encountered as well features connected to quenching pool. This quenching pool was not, however, directly observed. The structures and features within Trench 3 were originally situated within the core of the plate rolling mill. Within Trench 4, remains associated with the western wall of the annex were encountered. Within Trench 5, the main floor of the plate rolling mill was uncovered, which included, most notably, the base of the plate flattening machine. Finally, within Trench 6, the remains of the annex and mill proper were encountered, much like within Trench 2. Again, the base of the shears was recorded, as well as a feature likely associated with a quenching bosh, both of which were situated within the southern end of the rolling mill building.

4.1.2 As the archaeological remains discovered throughout the project relate to a rather technical set of processes, it is worth detailing here for purposes of clarity a broad outline of these processes' background. First of all, a *plate* rolling mill can be differentiated from a *sheet* rolling mill, as different grades or gauges of metal were produced in each. However, this difference was based largely on historical circumstance and was not necessarily applied universally across Britain or indeed the rest of the world. This means that while it was always accepted during the 19th century that a sheet was thinner than a plate, the degree of thickness separating the two was not. This naturally implies that a plate rolled in one copperworks might be considered a sheet in another, or *vice versa*. This does not necessarily apply throughout most of the 20th century, as grades of metal were more or less standardised, with *plates* being of 6mm thickness or above; *sheets* being between 0.5mm and 6mm thickness; and *foil* being less than 0.2mm thickness. Furthermore, the use of copper plates and sheets differed. Plates were generally used for marine purposes, particularly as material to construct ships' hulls, but were also used to manufacture boilers, ordnance, electrical equipment, and so on. Sheets, on the other hand, were mainly used in the manufacture of more diminutive items, such as coins, wire, minute mechanical parts, and so on.

4.1.3 The majority of the archaeological remains uncovered within the study area related to copper plate manufacture between approximately 1910 (when the Hafod plate mill was erected) and 1980 (when the works were demolished). More specifically, it is assumed that these operations related to the final stages of copper plate manufacture, which involved removing surface imperfections from pre-rolled plates and shearing them to size. The rolls within which these plates were formed were

situated to the north of the study area, within what was the northern end of the Hafod plate rolling mill. This area of the mill is now situated within the confines of the Musgrave Engine and Rolls Scheduled Monument (SMGm483). The process of rolling copper ingots or bars to plate (or indeed sheet) form is, in principle, a simple one. This process generally involved passing ingots through pairs of vertically aligned rolls, which would rotate in opposite directions (see Plate 87). The type of machine that facilitated this operation is known as the 'two high' rolls. The initial feeding of the metal through the rolls is known as the 'live pass', and historically the metal was then passed over the top of the rolls so that it could be fed through again. This passing of the metal over the rolls is known as the 'dead pass'. The inclusion of dead passes within the rolling operation naturally led to a decrease in the operation's efficiency. As a solution to this problem, the 'three high' rolls were introduced during the mid-19th century, which comprised three vertically aligned rolls. When this machine was in use, the metal would be fed through the lower and middle rolls before being passed in the opposite direction through the middle and upper rolls, meaning a dead pass was avoided altogether. Later, in 1872, 'four high' rolls were introduced, although these were rare and were used mainly in the manufacture of wrought iron piles (Mackintosh-Hemphill Co 1953, 30). Alternatively, a reversing mechanism could be installed within the two high rolls, meaning that sections of metal could be passed forward and backwards through the machine as two consecutive live passes. This type of machine was introduced in Britain during the 1860s, mainly via John Alleyne and later by John Ramsbottom (Gale 1967, 103). The rolls used at the northern end of the Hafod plate rolling mill were of the reversing two high variety. In between the Musgrave steam engine and the rope drive that it powered was a gear reversing chain (which can still be viewed today within the Scheduled Monument). This gear was operated by a driver from an elevated platform, which allowed sections of copper to be rolled via consecutive live rolls, with the gear allowing continuity between all live rolls.

4.1.4 Based on the findings from both the archaeological field evaluation and available photographic and cartographic evidence, a functional description of the operations conducted within the Hafod plate rolling mill can be formulated. These operations were those immediately following the passing of copper ingots between the reversing two high rolls, as detailed above. The northernmost features uncovered during excavations that pertained to the interior of the mill proper was the southernmost of four annealing furnaces, numbered [318] (see Plate 88 for reference). This particular furnace belonged to a pair of large, rectangular furnaces, which were themselves situated south of another pair of smaller furnaces, squat in form. Based on the archaeological evidence, it seems that the former pair of furnaces annealed sections of copper before being plunged into the quenching pool situated to the south, tentatively numbered [329]. The smaller pair of furnaces further north, according to the cartographic evidence detailed in Figures 15–16, which dates to 1945, did not appear to be accompanied by a quenching pool. This may serve as an indication that sections of copper underwent two stages of annealing at this point in the mill's operations, with the first stage involving heat treatment within the smaller furnaces, and the second stage involving heat treatment within the larger ones. Alternatively, it may be suggested that the smaller and larger furnaces had entirely different functions,

meaning that they were not necessarily used consecutively and were not part of the same chain of operations. The presence of a quenching pool to the south of the larger furnaces indicates that, once removed from these furnaces, the copper may have been too hot, and therefore too malleable, to be subjected to the flattening process that followed. In other words, flattening at this stage may have warped the copper to an undesirable extent, or it may even have been punctured entirely. It may be suggested, therefore, that plunging the copper into the quenching pool would have solved this problem.

4.1.5 After being removed from the quenching pool, the copper would have been at the correct temperature for flattening and would have accordingly been transferred to the plate flattening machine, where any imperfections in its surface were flattened out. Remains associated with this plate flattening machine were encountered in Trench 5, as represented by feature [504]. Conclusively determining the precise form of this machine remains difficult. Those assembled during the late 19th century comprised a twin set of rollers through which unfinished plates would pass. These were similar in appearance, although different in function, to a two high rolls. As was intimated by Haldane (1893, 124), who was writing at this time, this method of levelling plates sheets replaced those older operations which involved manual hammering. However, a photograph of the interior of the Hafod plate rolling mill appearing to show this same machine in operation (Plate 85), indicating that it flattened copper plates via the use of a vertically set hammer. This photograph also shows that the plates were position onto a flat surface beneath the hammer by hand and that the plates were rotated or re-positioned within the machine by workers holding large tongs. This, in turn, serves as an indication that the plates were of a sufficiently high temperature to be warped by the hammer. The date of this photograph is unknown, although it is was clearly captured in the 20th century. This is also supported by the fact that, in the bottom left of the photograph, an electric cable is seen feeding into the machine, indicating that it was powered by electricity and not steam. This cable is shown as projecting upwards from beyond the line of the mill floor and is also shown as running vertically along an RSJ. This same set up was encountered within Trench 5, as demonstrated by RSJ [511] and the remains of an electric cable situated within its vicinity. It is therefore possible that Plate 85 is indeed a photograph of the plate flattening machine within the mill.

4.1.6 Upon removal from the plate flattening machine, the copper was then transferred to the shears where it was cut into plates, or at least trimmed to plate size, before being transferred to the quenching bosh where it was brought to a far lower temperature, possible even room temperature. Remains associated with the shears were encountered in Trench 2, as represented by feature [223], as well as in Trench 6, as represented by feature [615]. A feature likely associated with the quenching bosh was uncovered in Trench 6, as represented by [617]. This feature is difficult to interpret precisely, yet its narrow form, which contrasts with the wide form of the bosh (as demonstrated in Figure 17–18), suggests that it was attached to the quenching bosh. As detailed above, this feature could be interpreted as a machine base for lowering and raising plates in and out of the quenching bosh. It could be assumed that the quenching bosh constituted the final stage in operations, however as indicated by both the 1946 aerial photograph of the works (Figures 23–24), as well as the 1951 plan

(Figures 17–18) the plate rolling mill extended approximately another 30m southward. This indicates that the copper may have undergone several more stages of refinement after being sheared, before being converted into finished plates. Finally, it will be observed that, in consideration of the placement of the live rolling tables within the mill, the annealing stage of plate production was mechanised, while the flattening and shearing stage was performed manually. This likely indicates that the latter two processes involved a level of technical intricacy and expertise that a machine could not perform. It should also be noted that it should not be assumed conclusively that the quenching of copper within the bosh proceeded its rolling.

4.1.7 Many of the operations conducted within the plate rolling mill were powered by the Musgrave steam engine, situated within the curtilage of the Musgrave Engine and Rolls (SMGm483). The discovery of the hot well approximately 25m southwest of the Musgrave engine house (feature [141]) represented a major finding, as it tied the Musgrave steam engine and the plate rolling mill together. In summary, the hot well allowed the Musgrave engine to run as efficiently as possible by retaining hot water for the boilers. In this respect, the cooling down of water, and therefore the reduction in heat, was minimised, leading to an increase in efficiency and even production capacity throughout the works as a whole. Therefore, the archaeological remains associated with the study area and the Musgrave Engine and Rolls Scheduled Monument (SMGm483) further north, on a functional level at least, cannot be separated, as they formed part of the same system of operations.

4.1.8 <u>The Hot Well</u>

4.1.9 Below, Tom Henderson details both the processes that enabled the operations of the hot well and the mechanical system to which it belonged was rather intricate. In essence, the hot well was invented in order to ameliorate certain deficiencies associated with the separate condenser of James Watt's atmospheric steam engine. For the purposes of keeping them at a consistently low temperature, so that steam for the exhaust pipe could be properly condensed, the Watt separate condenser and air pump were kept in a cold water tank. Once the steam was condensed within the separate condenser, the water pump would transfer it back into the boilers. In other words, when the water from the separate condenser was being recirculated back into the boilers, it was in a cold state, meaning that additional, and therefore unnecessary, energy was required to re-heat this recycled water. With the addition of the hot well, this re-heating stage was bypassed. Within the hot well, which fed directly into the boilers, water was kept at a consistently high temperature, meaning that significantly less energy was wasted in the operations of the steam engine.

4.1.10 With reference to the specificities of the hot well attached to the Musgrave steam engine at the Hafod site, Henderson summarised the following:

4.1.11 The Musgrave engine, although built some 141 years later than Watt's, and despite being a high speed and high-pressure engine as opposed to Watt's low-pressure and slow atmospheric engines, still used a separate condenser water pump in much the same way, generating a vacuum by condensing the exhaust steam and raising the engines in an efficient way. This is also an important safety mechanism for an optimised Uniflow type engine, where without a vacuum the engine risks over-pressurising, potentially causing catastrophic damage. The arrangement of the

Musgrave engines steam and water circuits at the Hafod Copperworks are unique to the site and although in many cases less than ideal they reflect the development of the works and how it came to outgrow its compact site. For example, in an early proposal dated April 28th 1910 (Plate 89) Musgrave and sons intended to build a range of boilers immediately adjacent to the Musgrave engine house in order that the engine be fed with the driest, high pressure steam; curiously shown tied into the existing range of boilers some 100 yards away. Plate 92 also demonstrates the position of the hot well within the Hafod works at this time. Vivian and sons, it seems, chose to stick with their existing boiler infrastructure. The re-use of the hot water emerging from the engine's condenser does not appear to have been a consideration; instead it was piped off to a nearby, pre-existing culvert which is presumed to have once out-flowed to the River Tawe. This was not ideal, as much heat and energy was lost in piping steam from a distance. These problems would later have been compounded when the Hafod and Morfa works combined and the Musgrave engine came to share a common boiler range 300 feet away. (YIM Uniflow document).

4.1.12 The sheer volume of warm water pumped from the condenser may offer some explanation as to why a hot well was not initially adopted for the Musgrave engine. In the late 1970s, some 22,000 gallons per hour was calculated to pass through it and the cooling tower (see YIM Uniflow document), and recovering this heat would have been impractical; better to reap the efficiency of a cool condenser with a ready supply of canal water nearby. This, however, was not to last as the Swansea canal fell out of use in the late 1920s and was gradually filled in. The combined Hafod Morfa works (1926) would then have needed to find a solution to the impending loss of this water supply in order to keep rolling. Records are far from complete but drawings dated 19.1.1945 (Plate 90) show a proposed hot well immediately in front of the Musgrave engine house's main doorway and a surviving analogue to this proposed underground structure is situated near the base of the adjacent chimney today. The later hot well shares many of the same features; outflow and overflow pipe, electrically driven pump, but this one curiously is sending water back into the canal. An ICI drawing annotation suggests a real date of somewhere prior to 1958 with the formation of Yorkshire Imperial Metals. It appears that this was never put into action (as per Plate 90), or was at best short lived, as indicated by the inked in valve. Moreover, it appears that alternate pipework was not fitted, as the outflow from the Musgrave condenser survives (as per the original drawing No 34830, March 7th 1911) (Plate 91), although having suffered some damage. An assumed slightly later plan of the works also dated 19.1.1945 (Plates 94–6), however, shows the recently discovered hot well – it would appear that this hot well was the final solution employed until the engine last ran in 1980 (Plate 97). It would also appear that the drawing office re-used the same W.P. 138 Works plan for many purposes, and often failed to annotate the date of any proposals or amendments. The real date of the hot well's installation likely occurred between 1945 and 1958.

4.1.13 Although the location of the hot well seems strangely distant from the engine it must be noted that it is a consequence of the geography and pre-existing structures on the site. Condenser outflow, although "pumped", was achieved mainly by the force of gravity, and exit direction from the engine house was dictated by engine arrangement and convenience of a nearby culvert to the south, perpendicular to the centreline of

the engine house. From the outset, the outflow had to avoid the earlier chimney adjacent to the engine house and would have been set lower than the rolling mill furnace flues. Later, when a site needed to be found for the hot well, there was only one area suitable that was low enough and which would not interfere with the operations of the rolling mill, railway line, roadways and furnace flues.

4.1.14 The YIM Uniflow document in Appendix IV is an important piece of the puzzle and demonstrates that there was open dialogue between works management and a prospective owner operator of the Musgrave engine in the late 1970s (approaching the works closure). It clearly confirms the function and albeit rough location of each element of the then extant water and steam circuits and cements the link between the hot well 'tank' found during the dig and its association to the Musgrave engine. This ties in with a later works crane plan of 1975 (Plate 93), identifying the location of the cooling tower on a platform where the pre-1910 boilers stood, and of course the hot well itself. Tying this document with its diagrams to works drawings and archaeological finds has been a satisfying exercise and removes any doubt that the description of the engine in the YIM Uniflow document and its associated water and steam circuitry was inaccurate.

4.1.15 Quite simply, without this additional water collection and re-distribution infrastructure, the Musgrave engine would not have been able to keep on functioning efficiently and rolling capacity at the mill would necessarily have to have been greatly reduced. Certainly, in the ever more competitive post-war climate the Hafod Morfa works could little afford to lose use of their greatest advantage – the widest rolling mill rolls in Europe needed a lot of power to keep them turning. The hot well is integral to the Musgrave engine and rolling mill infrastructure and demonstrates adaptation to the modernising world around it. It is also a vitally important surviving element in the pursuit of restoring and running the engine once more in preservation.

4.1.16 <u>19th century Structural Remains</u>

4.1.17 Although scant, some structural remains of 19th century date were uncovered during the archaeological field evaluation. These remains are difficult, if not impossible, to interpret at present with any degree of accuracy. However, as has been intimated within Section 3, they may have originally belonged to the Hafod Hammer House, which occupied the study area between approximately 1819 and 1910. According to Hughes' speculative plan of the Hafod works (Figure 13–14), the Hammer House may have originally occupied large parts of the excavation area. However, the only trenches that yielded evidence of structural remains that potentially derived from the Hammer House, or at least a structure of 19th century date, were Trenches 2 and 6. More specifically, these remains comprised walls, both of which appeared to be aligned in a broadly N/S direction. In consideration of the Hughes' plan, in could be tentatively suggested that the 19th century wall uncovered at the eastern end of Trench 2 was the eastern wall of the Hammer House, while the wall within Trench 6 was potentially a partition wall situated within the confines of the Hammer House. However, as Hughes' plan is a speculative one, any precise interpretation of these features is, at present, impossible. What can be said with at least some degree of certainty is that the 19th century structural remains on site were only partially observed and there exists the likelihood that, if excavations were conducted at a wider

or deeper level, then significantly more 19th century remains would have been uncovered. At present, our knowledge of the 19th century history of the study area remains incomplete.

5 Community Archaeology

5.1 Introduction

5.1.1 The principle objectives of the Copperworks Discovery Project 2021 were directed at bringing archaeological practice and the industrial heritage of the Lower Swansea Valley to a wider and more diverse audience. Specific community outreach objectives were identified as follows:

1. To provide all participants with a positive experience of archaeology, allowing them to take ownership of their own heritage.
2. To engage a broad range of intergenerational community groups such as vulnerable adults and schoolchildren with the project, promoting the importance and value of local heritage in the Lower Swansea Valley.
3. To increase access to employable skills in the field of archaeology for groups outside of the university education system, providing the novice archaeologist with an entry-level skillset of archaeological techniques from which they can build.
4. To maximise public engagement with both the industrial archaeology of the area and the programme of activities taking place through a digital social media campaign, blog and vlog posts, and pre-commencement and post-excavation virtual engagement events.

5.1.2 Black Mountains Archaeology Ltd undertook a comprehensive programme of pre-commencement and fieldwork engagement activities designed to accomplish these learning outcomes. Participant and visitor feedback surveys were employed to test their success.

5.2 Programme

5.2.1 **Pre-commencement Activities**

5.2.2 A co-ordinated social media campaign to promote the project and attract volunteer participants took place. A media launch date of Wednesday 13th October 2021 was agreed between all stakeholders, with a digital flyer promoting the project and virtual launch event in both English and Welsh disseminated on this date (Appendix V).

5.2.3 Details of the project were shared widely on social media in order to engage a diverse audience. The project was promoted on social media via Black Mountains Archaeology's Twitter, Facebook, and LinkedIn social media accounts. The promotional flyer alone achieved a reach of 15,300 with 1,000 engagements on Facebook (see also Appendix V).

5.2.4 In co-ordination with Dr Tracy Evans of Swansea University the project was shared with local charities such as The Wallich; Wales' leading homelessness charity. Local intergenerational community groups with an interest in the Hafod-Morfa Copperworks and the practice of archaeology were also approached, for example the Friends of the Hafod Morfa Copperworks group. Dr Tracy Evans managed engagement with local primary schools. Regular updates and reminders aimed at maximising engagement were shared via email and social media in the weeks preceding the launch of the project.

5.2.5 A pre-commencement launch event hosted by Black Mountains Archaeology Ltd and was held virtually on the Zoom platform on Tuesday 26th October at 7.30pm. The event offered attendees a broad overview of the history of the Hafod-Morfa copperworks, discussion of recent excavations, information for volunteers, and a Q and A session. The event was attended live by 35 individuals and a recording posted on Youtube, watched a further 173 times, was shared both on social media and directly with all interested parties.

5.2.6 **Volunteer Participants**

5.2.7 From the 56 individuals who registered interest in the project 31 individuals physically attended as volunteers. Unfortunately, inclement wet weather which persisted throughout the week of fieldwork activities deterred a number of confirmed volunteers. Participants were offered at least one full day of work on site and each person invited to indicate which days they would be available. The provision of half-day sessions was popular amongst participants. Due to the former industrial nature of the site, fieldwork participation was restricted to those over the age of 18.

5.2.8 The project attracted a wide demographic of individuals ranging in age from 19-84. 12.9% of participants requested adjustments to their activities based on physical and/or mental health concerns. One participant attended the project as a resident of The Wallich homeless hostel. Events such as the Copperworks Discovery Project offer prime opportunities for those subject to homelessness to gain essential employability skills. A total of 83.9 percent of participants were not current university students and may otherwise have failed to access such fieldwork activities. Six volunteers attended from community groups with an interest in local heritage, many with personal links to the Hafod Morfa Copperworks. Carolyn Jones, age 84, was a former employee in the laboratory of the Hafod-Morfa Copperworks from 1956-1964, one of a small number of female employees. Carolyn participated in the project on two days and learned archaeological skills such as trowelling and scaled section drawing. Arthur Green age 68 had visited Number 1 rolling mill as an apprentice on the Musgrave Engine's final day of operation in 1980. Arthur participated for two days, gaining skills such as scaled plan drawing, context recording, and static site photography. He also shared a number of original photographs he took of the works prior to its demolition.

5.2.9 **Fieldwork Activities**

5.2.10 The start date for field operations was Monday 8th November 2021. Community excavation activities commenced for five days until Friday 12th November 2021. Field operations concluded with backfilling of the site on Tuesday 16th November 2021.

5.2.11 Each day of the community excavation was divided into a morning and an afternoon session. Morning sessions ran from 10am – 12.30pm, and afternoon sessions from 1.00pm – 3.30pm. A break for lunch took place each day from 12.00-12.30pm. Participants were offered the opportunity to volunteer for full or half days. A cap of 15 participants per session was imposed to ensure that a maximum ratio of five volunteers to each archaeologist was observed. One additional archaeologist was assigned to overseeing project co-ordination and digital engagement.

5.2.12 Upon entry to the designated site of excavation each new participant undertook site induction training to become a formal volunteer. Induction training content included

but was not limited to guidance on risks specific to industrial excavation, working around machinery, personal protective equipment (PPE), Covid-19 mitigation, first aid procedure and fire procedure. Each participant was required to sign a declaration confirming that they had received a site induction detailing the potential hazards of working on an industrial site. A copy of the site risk assessment was made available to all participants. Ground contamination identified at the former metalworking site required that participants wear full PPE including type 5/6 coveralls and nitrile gloves as a precaution. Damp ground conditions meant that P3 respirator masks were not required but available on request. Work gloves, hard hats and eye protection were also provided. Hand tool demonstrations were carried out upon request. Air monitoring was carried out during the investigations (Trenches 1-6) to test for the presence of asbestos fibres potentially disturbed by the excavations. No fibres were identified in any of the samples.

5.2.13 The team of archaeologists adopted a constructivist approach, working as conduits through whom the volunteers could gain archaeological skills and therefore guide the direction of their own excavations. Individuals with specific interests in the site and/or an industrial process were encouraged to make informed decisions on the location of trenching based on maps and plans available on site.

5.2.14 At the beginning of each session participants were offered the opportunity to undertake a choice of tasks encompassing the archaeological process. Volunteers attending more than one session were supported to learn multiple archaeological skills. Transferrable employability skills included but were not limited to; dumpy level surveying, machine watching, hand excavation with a range of hand tools, trench cleaning, static site photography, scaled plan and section drawing, and site context recording.

5.2.15 **Local School Visits**

5.2.16 During excavation activities four groups of school children and staff members from three local primary schools attended the copperworks for pre-arranged visits. By the end of the week a total of 107 children aged 8-11 had participated in the visits. These visits were overseen by one archaeologist and one staff member from Swansea University.

5.2.17 Each session lasted one hour and was divided into two distinct engagement activities with associated worksheets (Appendix VI). A ‘treasure hunt’ of the Hafod-Morfa Copperworks site saw the children tour the site on a pre-determined route whilst locating nine images displayed on a worksheet. Each image related to a talking point introduced by the archaeologist and discussed with the children. The treasure hunt concluded at the entrance to the excavation site. The ‘Guess the Find’ activity required the children to view six artefacts discovered on previous excavations at the copperworks and to speculate their function. The artefacts were on display and a worksheet featuring images of each find and space to write their thoughts distributed. The children were then encouraged to share their ideas before the artefact’s true function was revealed.

5.2.18 Throughout both engagement activities comments and interpretations from the children were encouraged at all times and the level of teaching made age appropriate.

The 'Guess the Find' activity took place within a designated, enclosed area of the excavation site, a safe distance from volunteer and heavy machinery activity. The children were invited to view the excavation from that location whilst a discussion of the role of an archaeologist took place. Ground contamination and the presence of heavy machinery unfortunately prevented physical interaction between the school groups and excavation activities.

5.2.19 **Digital Engagement**

5.2.20 A comprehensive programme of digital engagement was undertaken to promote the project, facilitate wide dissemination of its' progress and to act as a public resource.

5.2.21 Following on from the pre-commencement media campaign, daily updates were posted to Facebook, Twitter and LinkedIn for the duration of fieldwork activities. Facebook posts created by the hosts and relating to the project received in excess of 2,000 engagements. Twitter tweets amassed 367 likes and retweets. LinkedIn posts accumulated 1,833 impressions (see also Appendix V) All questions, both private and public, were responded to in a timely manner.

5.2.22 A comment box within the participant contact sheet completed by all potential volunteers enquired how each individual learned of the Copperworks Discovery Project. The highest proportion (26 percent) quoted social media as their initial source.

5.2.23 Four 3-dimensional photogrammetric models of archaeological discoveries were shared on social media platforms during fieldwork activities. All 3D photogrammetric models are hosted online as a public resource (see Section 2 above). Drone footage of site activity was recorded and shared as a promotional compilation. Vlog material such as interviews with participants and staff members and a site tour was compiled for use in future digital resources. The two engagement activities prepared for visiting school groups were shared as downloadable links for prospective visiting families to utilise in the future.

5.2.24 A virtual post-excavation event will be provided to publicise the community investigations and share concluding insights with all stakeholders. The event will include but not be limited to: edited vlog footage taken during fieldwork activities, discussion of the written report findings, and a question-and-answer session.

5.2.25 **Feedback Surveys**

5.2.26 A link to a digital feedback survey was shared with all participants and school visit staff members to test the success of the project's community outreach objectives and general learning outcomes. One survey was shared with individual participants and another with the lead staff member for each primary school involved in visits. Twenty-six individuals completed the participant survey, and four school staff members completed the visitor survey. The questionnaires were comprised of five statements and three questions with open-text comment boxes. All survey statements required a response however, free-text comments were optional. All responses were anonymous.

5.2.27 A list of all volunteers can be found in Appendix VII.

5.2.28 **Participant Survey**

5.2.29 Respondents were asked to grade four statements as:

A. Strongly Agree
B. Agree
C. Slightly Agree
D. Neither Agree Nor Disagree
E. Slightly Disagree
F. Disagree
G. Strongly Disagree

5.2.30 These statements were:

1. I enjoyed participating in the Copperworks Discovery Project 2021.
2. I felt that staff valued my contribution to the project.
3. I would be eager to participate in future archaeological investigations.
4. The project helped me to better understand the value of Wales' industrial heritage.

5.2.31 Respondents were also asked to respond to a Yes/No statement. The statement was:

5. I learned at least one basic archaeological skill.

5.2.32 Respondents were asked to respond to three queries in free-text comment boxes. The questions were:

1. Describe any aspects of your experience that you particularly enjoyed.
2. Is there any way you feel your experience could have been improved?
3. Do you have any further comments?

5.3 Results

5.3.1 There was a 100 percent response rate to the visitor feedback survey, with all four school staff contacts completing a submission.

5.3.2 As with the participant survey, both the statements and free-text responses indicate a high level of overall satisfaction from all school groups. All respondents gave a grading of 'strongly agree' to the statement: 'My school group enjoyed participating in the project', and no less than a grading of 'agree' to all further statements. Whilst three respondents felt that the children particularly enjoyed the treasure hunt engagement activity, two observed that studying the artefacts during the guess the find activity was popular among their group. Both engagement activities appear to have been well received, with positive experiences of the two activities referred to by all respondents. One particularly complimentary response read: '*The site visit was great and the children found watching others on the site fascinating too. Since we have been back they haven't stopped talking about their visit. I think some are even thinking about archaeology as a career choice!*'. The respondents went on to comment that… '*It was a simply fascinating visit and something they [sic] every child should have the opportunity to do – become a time detective!*'. Comments such as these underline the value of childhood engagement with local heritage sites.

5.3.3 While respondents agreed that the visits went well and all responded positively to future involvement, three of the four respondents suggested that it would have been

beneficial to have a closer alignment the archaeological fieldwork activities which were taking place during their visit. Unfortunately, ground contamination and the movement of heavy machinery prevented the school groups having any physical or proximal access to the excavation area. However, for any future events taking place around the copperworks a more in-depth discussion of archaeological process and greater reference to the fieldwork activities going on around them would make a valuable addition.

5.4 Discussion and Conclusion

5.4.1 All four general learning outcomes were achieved on this project. Guided by the team of archaeologists the field participants successfully excavated and recorded structures of international importance.

5.4.2 Participants overwhelmingly agreed that the project offered them a positive experience of archaeology. A total of 92.31 percent of respondents to the participant feedback survey *strongly agreed* with the statement 'I enjoyed participating in the Copperworks Discovery Project 2021', with the remainder selecting their response as *agree.* Equally indicative were participant responses to Questions 2 and 4. Open-text comments emphasised the assistance of staff, ability to learn new skills and try something new as highlights of their experiences. The staff of Black Mountains Archaeology found all volunteers to be engaged and eager to participate despite a very damp weather forecast throughout the week. It was a pleasure to watch the skillset of participants develop over the course of the week, with many reaching a level parallel to that of a trainee archaeologist. Nine of the twenty-one respondents to the 'any further comments' section at the end of the participant survey requested to be informed of future events. This insight is testament to the overall positive atmosphere of fieldwork activities and suggests that the project's overarching objective to provide participants with a positive experience of archaeology was achieved.

5.4.3 A broad range of intergenerational community groups were engaged over the course of the project, from schoolchildren up to individuals in their 80s. Thirty-one individuals, such as former copperworks employees, mixed with local heritage enthusiasts, university students and members of charity groups to create a small community united by an interest in archaeology. A total of 107 local schoolchildren appeared engaged and intrigued by the history to be found on their doorstep. Today's children will be keyholders to the heritage industry of the future therefore it is vital that they recognise the value of their local heritage. The Copperworks Discovery Project 2021 offered a prime opportunity to tackle that objective, and the enthusiasm of responses during the two childrens engagement activities suggest that this objective was successful. One member of the school visit support staff commented in their feedback survey that… '*Since we have been back they haven't stopped talking about their visit. I think some are even thinking about archaeology as a career choice!*'. That lasting impression underlines the importance of community engagement to the future of heritage and archaeology.

5.4.4 The project increased awareness and ownership of local heritage in the Lower Swansea Valley for participants. A total of 93.5 percent of attendees were residents of south Wales, and 77% residents of the Lower Swansea Valley. Each volunteer was able to quite literally uncover a piece of their own local history, and recognition of this

is reflected in many of the open-text responses from the participant survey. One respondent to the participant survey commented that '*I was undecided about joining in to start with as industrial archaeology isn't my main interest, but I thoroughly enjoyed the time and am grateful for the chance to do something I've always wanted to do, be involved in a real dig!*' A greater understanding of the value of Wales' industrial heritage resulted from this novice archaeologist's experience with the project, and this is overwhelmingly reflected by responses to the accompanying survey question. It is hoped that volunteer participation in future Lower Swansea Valley projects will benefit as a result.

5.4.5 A total of 83% of participants attended the project from outside of the university education system, evidence that the project successfully increased access to employable skills in the field of archaeology for non-university affiliated individuals who would otherwise struggle to access them. Communicating accepted standard archaeological practices to the participants was central to the methodology of this event. Participants decided which fieldwork tasks to undertake and although many opted for the physical act of 'digging' as their favoured function many others executed a range of archaeological recording skills. Open-text responses to the participant survey reflect the keen interest many had in gaining archaeological skills and the subsequent comprehension of what they were observing. For example, '*I enjoyed learning about getting a vertical surface on the sides of the trench, and actually seeing how good the layers looked and seeing how well it could give a timeline so you could understand what you were standing on*'. Another respondent commented that they enjoyed '*following a process through, from initial digging to cleaning up the trench for photography*.' A total of 96.15% of respondents felt that they had learned at least one basic archaeological skill during their time at the Copperworks Discovery Project. Many of the skills demanded of an archaeologist do not require a university education. This project was able to offer an entry-level skillset of archaeological techniques to individuals with otherwise limited access to the sector.

5.4.6 A comprehensive programme of digital engagement promoted the project, facilitating wide dissemination of its' progress and acting as a public resource. A successful social media campaign reached over 24,000 accounts and amassed nearly 1,000 interactions such as post comments and shares, demonstrating the undeniable value of digital promotion for maximising public engagement with heritage projects in the 21st century. The largest proportion of volunteers (26 percent) learned of the project through the host's social media campaign. None of these individuals had prior links to the copperworks, therefore it is unlikely they would have volunteered without the digital campaign.

5.4.7 The virtual pre-commencement event was attended live by 35 individuals and the recording viewed over 173 times since. The content of the launch event was verbally praised by participants for providing them an appropriate insight into the project before they committed to volunteering. Many commented that they had little knowledge of industrial archaeology, therefore, it is a safe assumption to conclude that this digital resource increased public knowledge of and engagement with the industrial heritage of the Lower Swansea Valley. Similarly, the digital models, daily photographic updates and video content which was shared during fieldwork activities

had the ability to reach intergenerational audiences unable to physically attend, such as those outside of the UK.

5.4.8 The Copperworks Discovery Project 2021 identified community outreach objectives aimed at bringing archaeological skills to a wider audience and increasing public engagement with the Lower Swansea Valley's rich industrial heritage. Despite a fieldwork period of just five days, the hosts launched an ambitious programme of activities which succeeded in recruiting 31 participants, involving three local primary schools and engaging thousands of people via digital resources. Responses to participant and visitor feedback surveys testify to the overall positive learning experience enjoyed by many who attended. The project has raised awareness that archaeology is accessible to all of us, and it is hoped to result in greater physical and digital engagement with future heritage events in the region.

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7 Appendices

7.1 Appendix I – Figures

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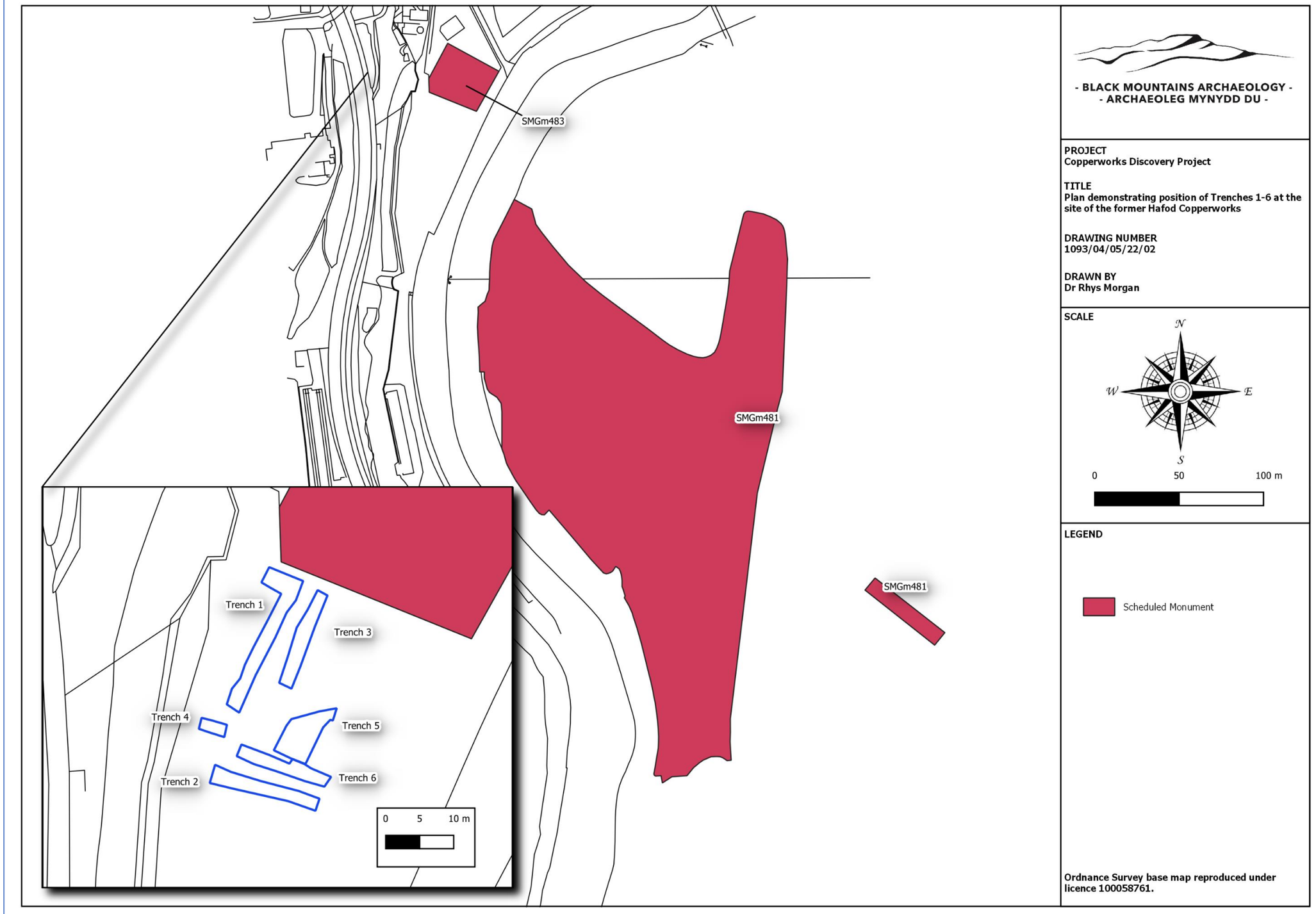


Figure 1. Position of Trenches 1–6 within wider landscape of Swansea

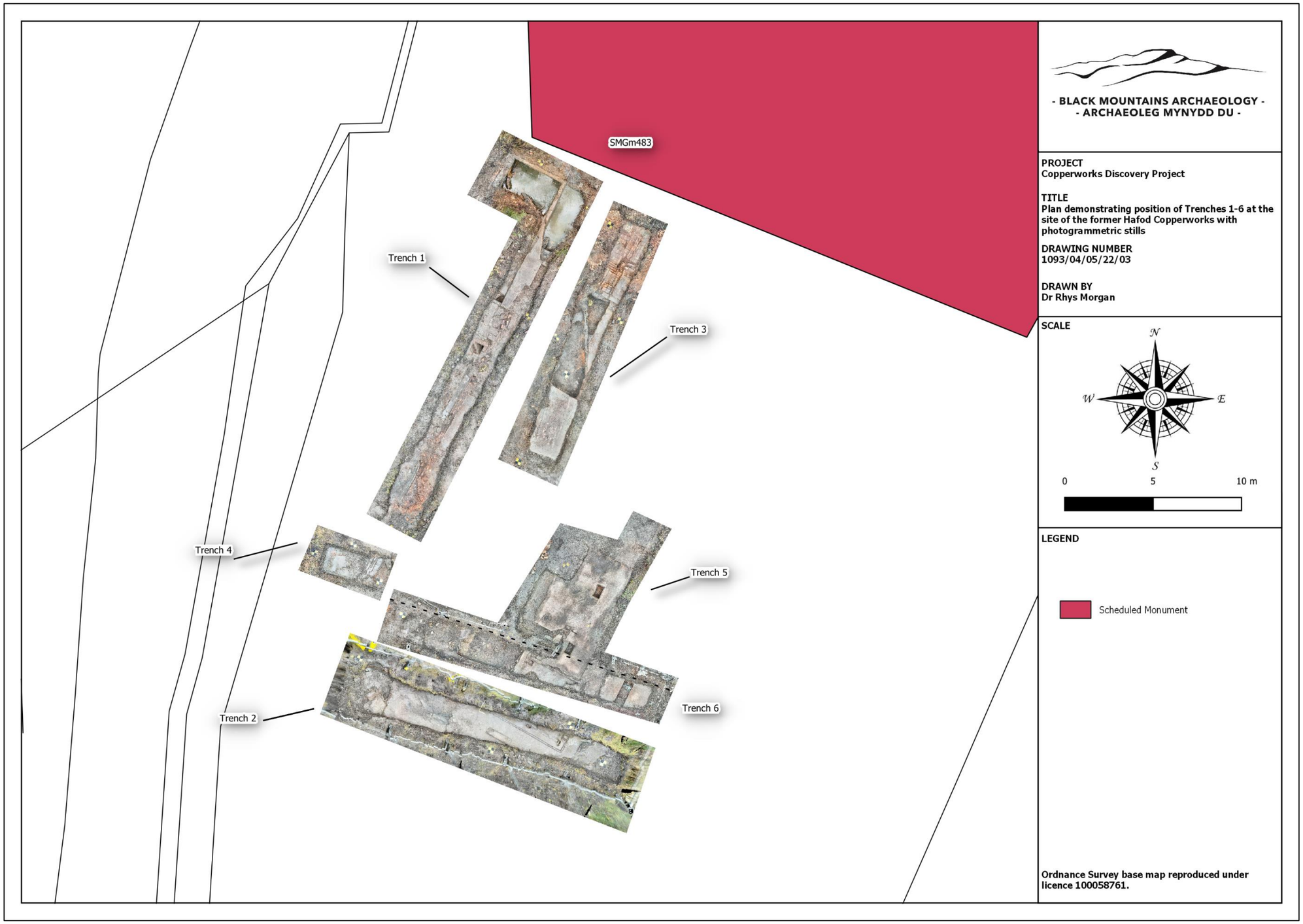


Figure 2. Photogrammetric orthographic plan showing position of Trenches 1–6 .

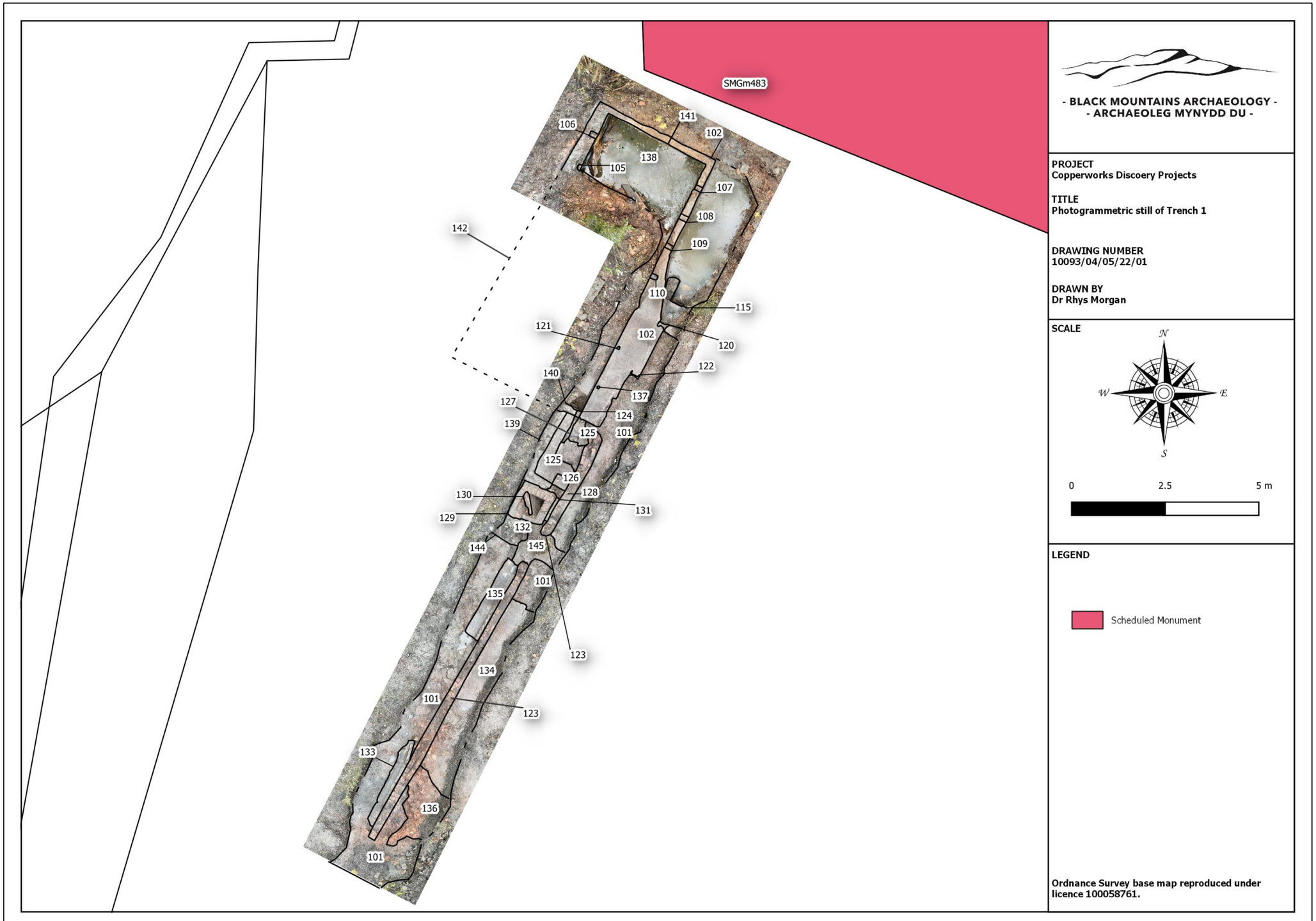
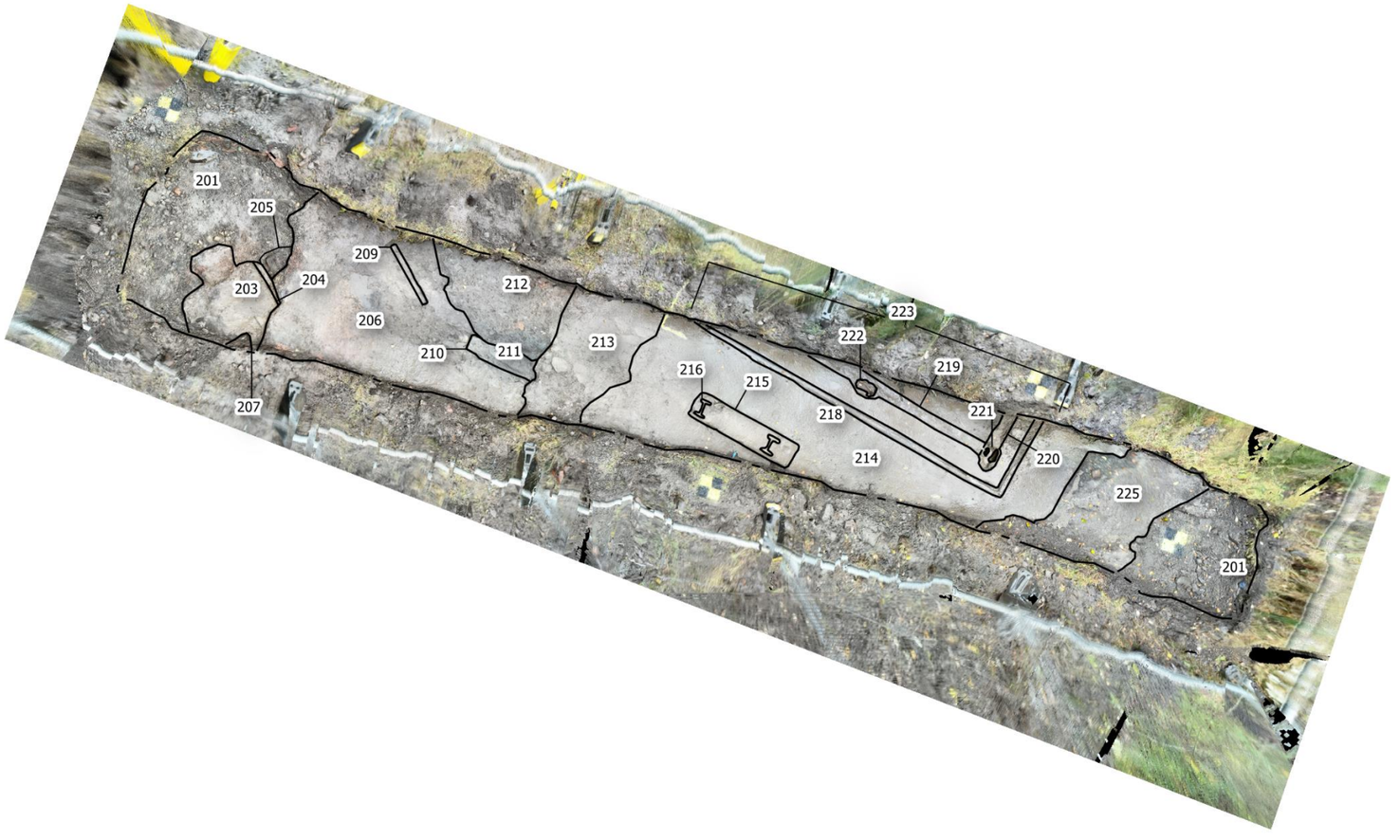


Figure 3. Photogrammetric orthographic plan of archaeological remains discovered within Trench 1



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TITLE
Photogrammetric still of Trench 2

DRAWING NUMBER
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Figure 4. Photogrammetric orthographic plan of archaeological remains discovered within Trench 2

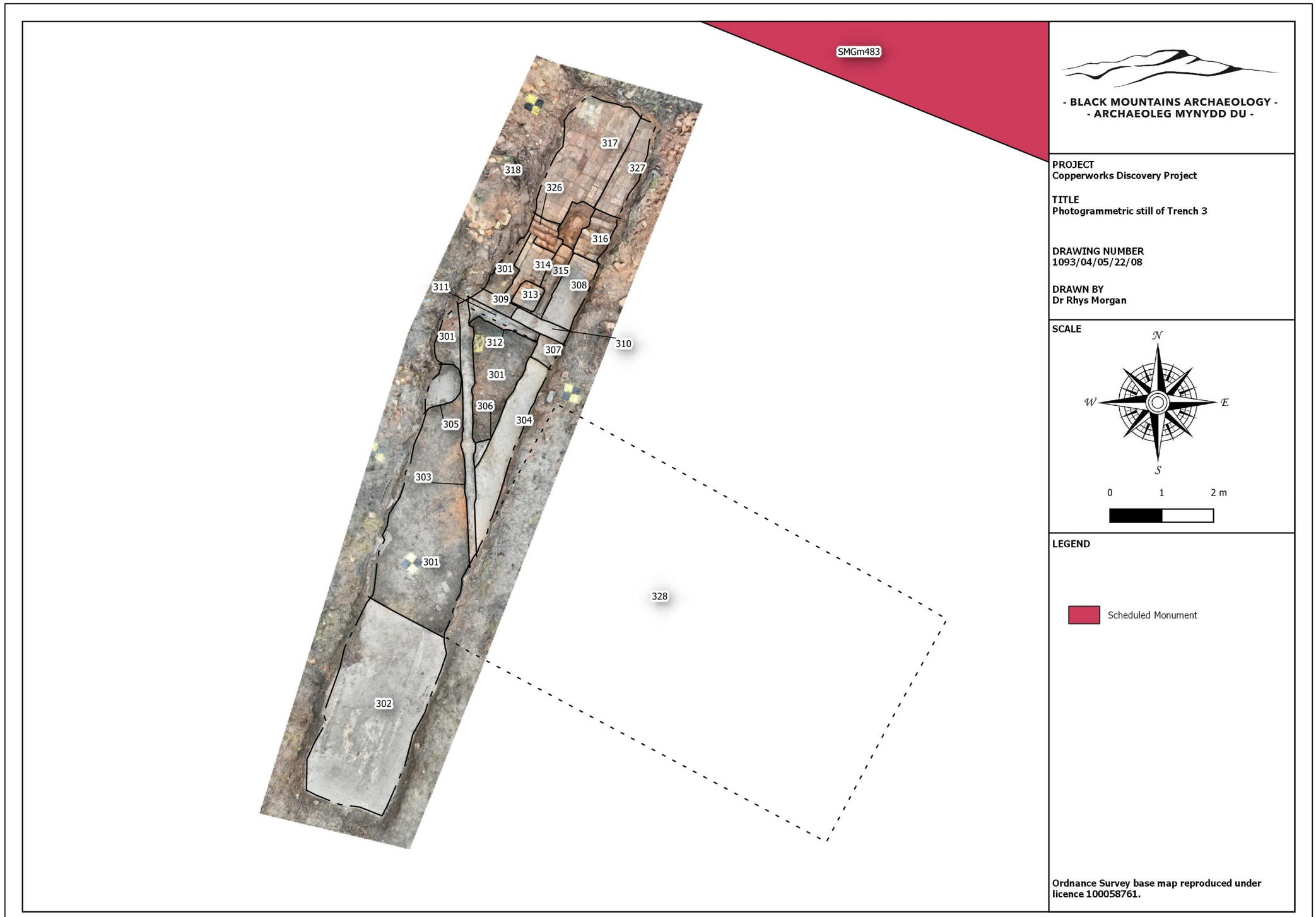
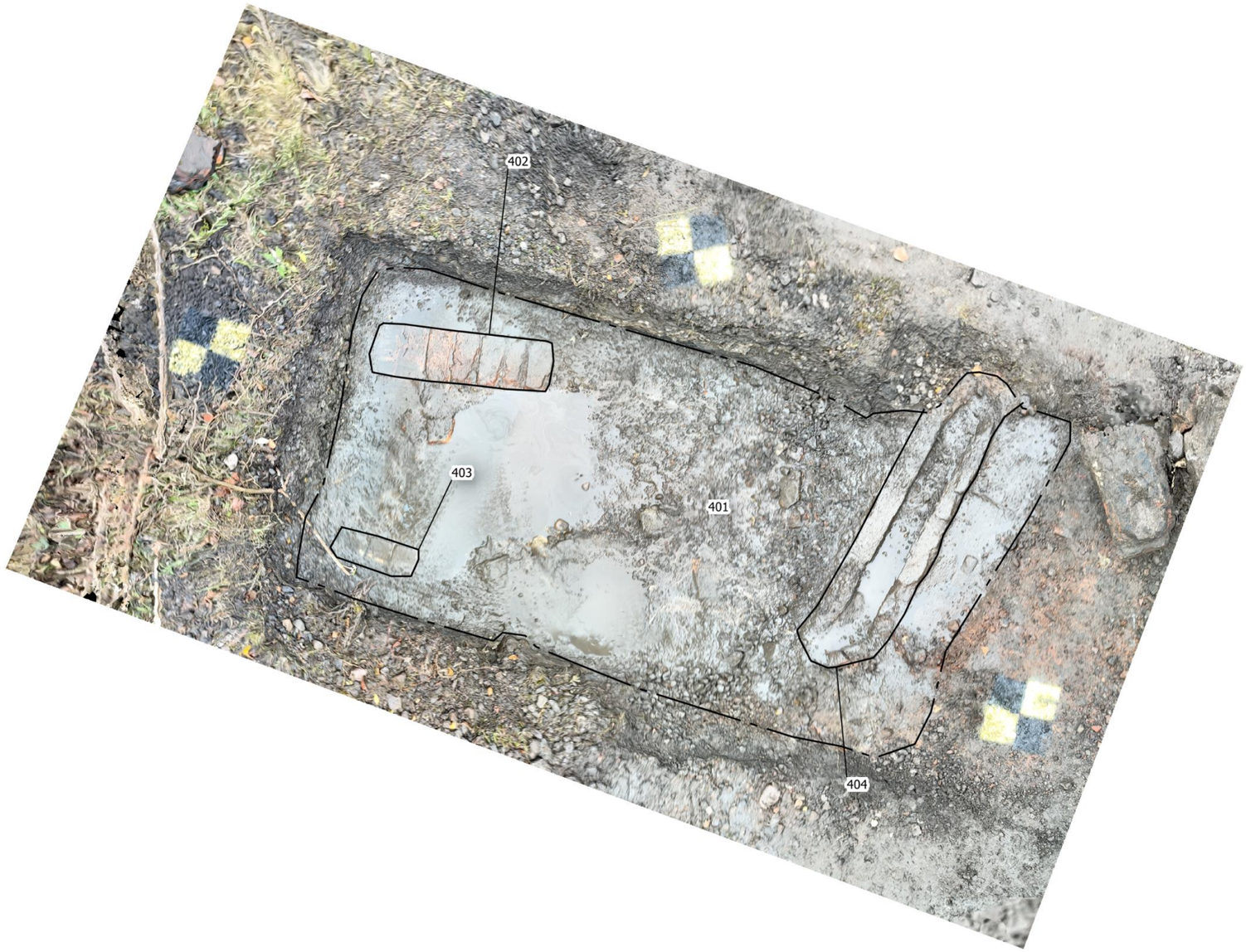


Figure 5. Photogrammetric orthographic plan of archaeological remains discovered within Trench 3



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TITLE
Photogrammetric still of Trench 4

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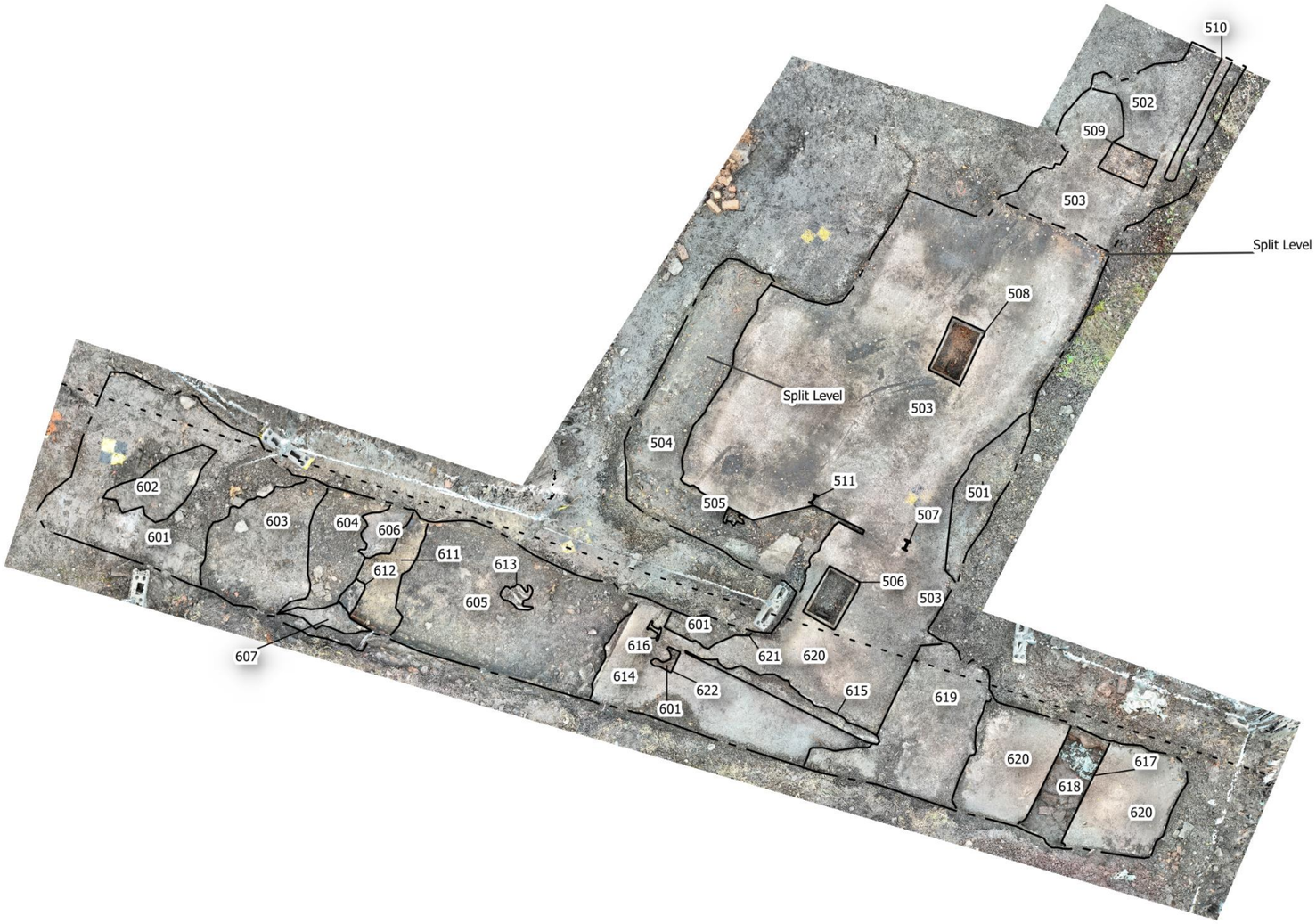
Figure 6. Photogrammetric orthographic plan of archaeological remains discovered within Trench 4



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TITLE
Photogrammetric still of Trenches 5 and 6

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Figure 7. Photogrammetric orthographic plan of archaeological remains discovered within Trench 5 (southernmost) and Trench 6 (northernmost) after their conjoining

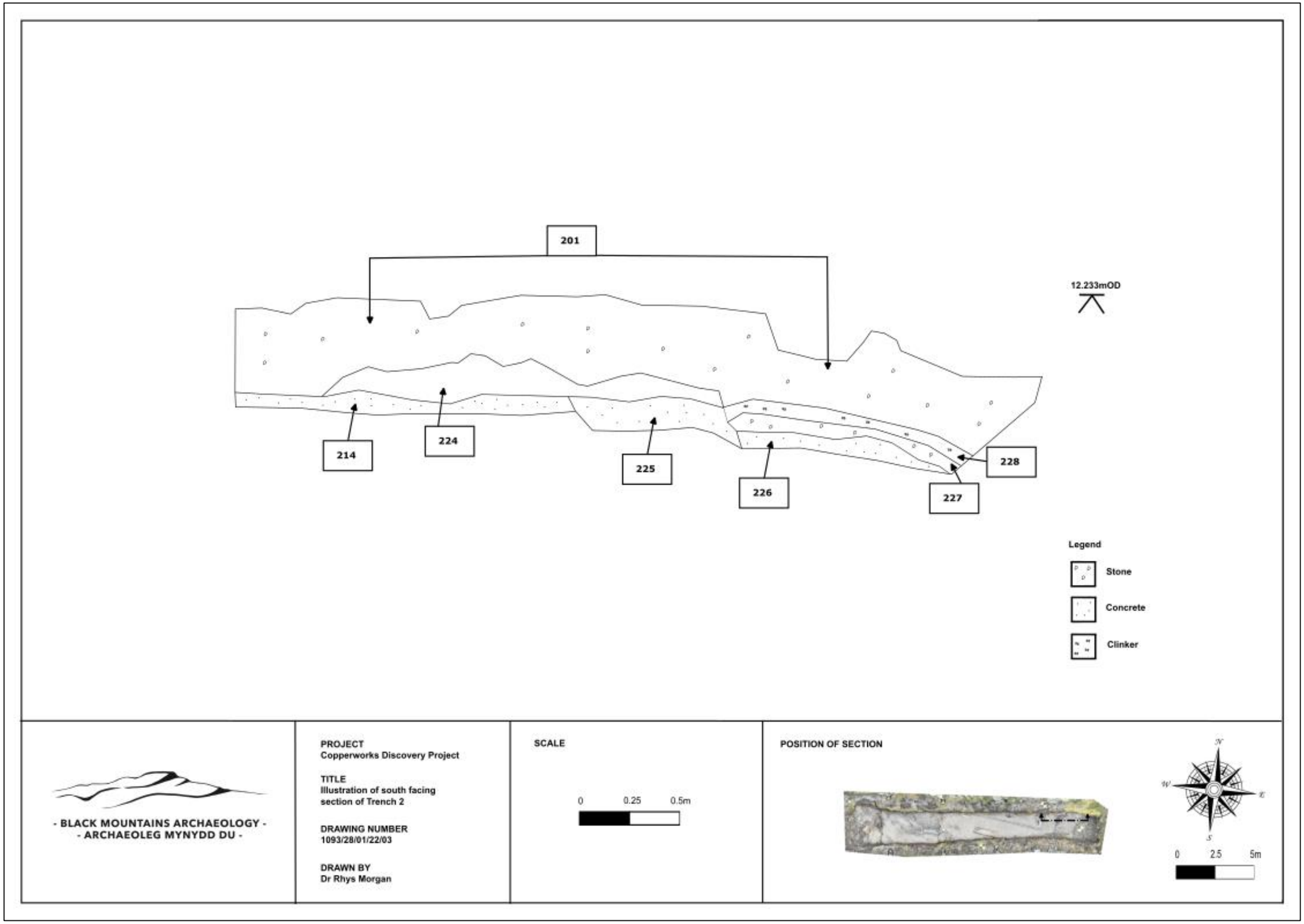


Figure 8. Illustration of south facing section of Trench 2

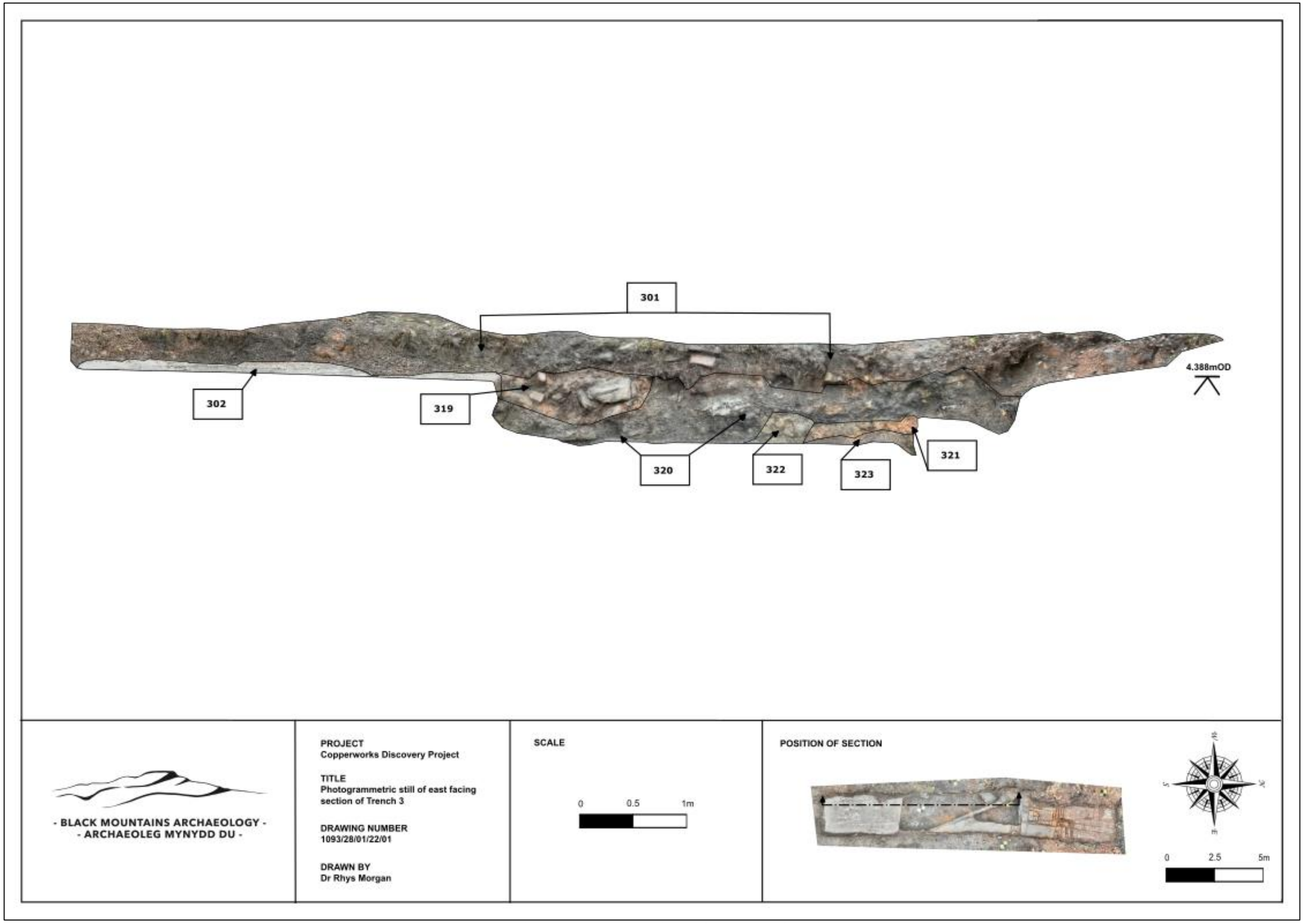


Figure 9. Photogrammetric orthographic east facing section of Trench 3

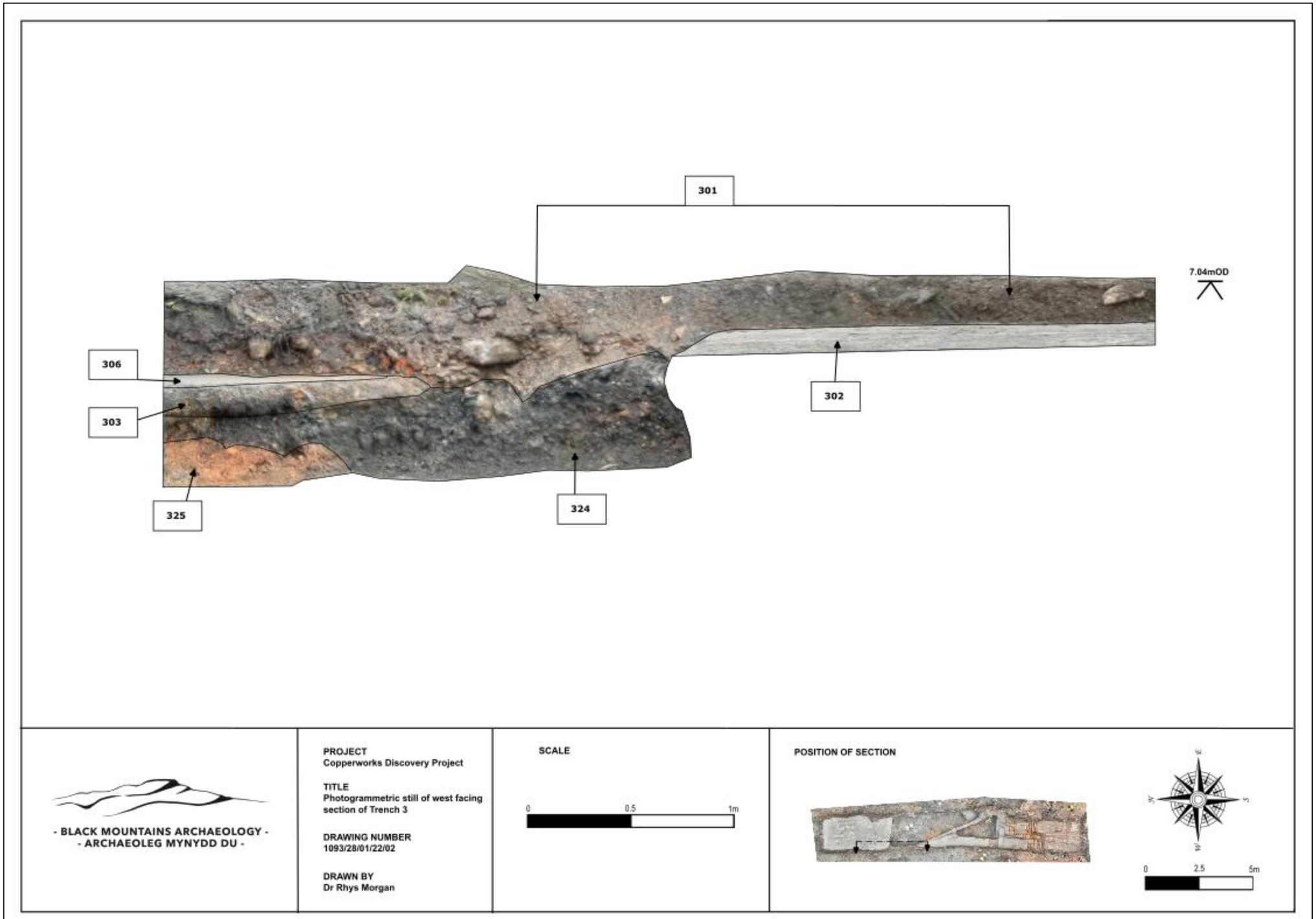


Figure 10**. Photogrammetric orthographic west facing section of Trench 3**

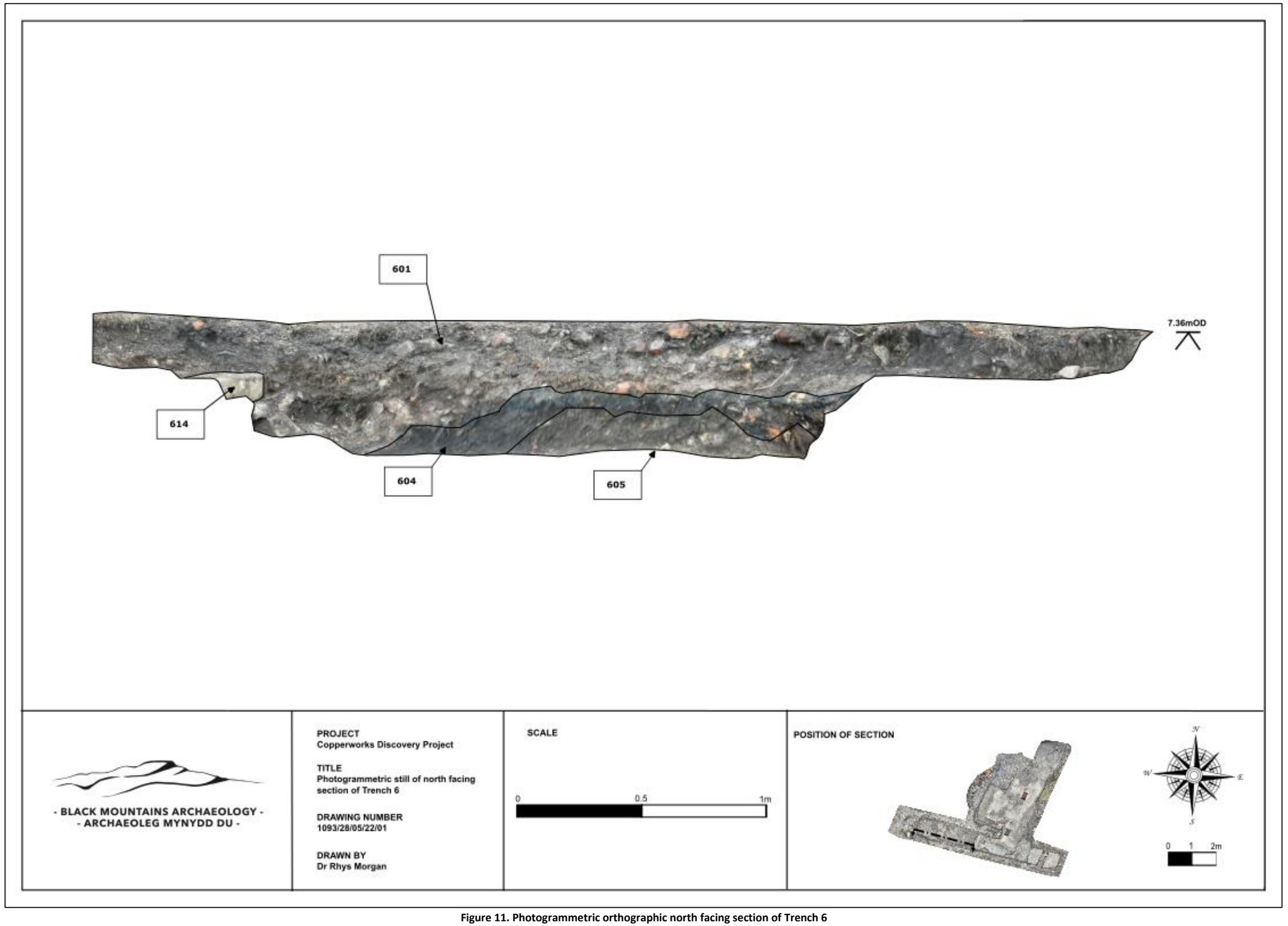


Figure 11. Photogrammetric orthographic north facing section of Trench 6

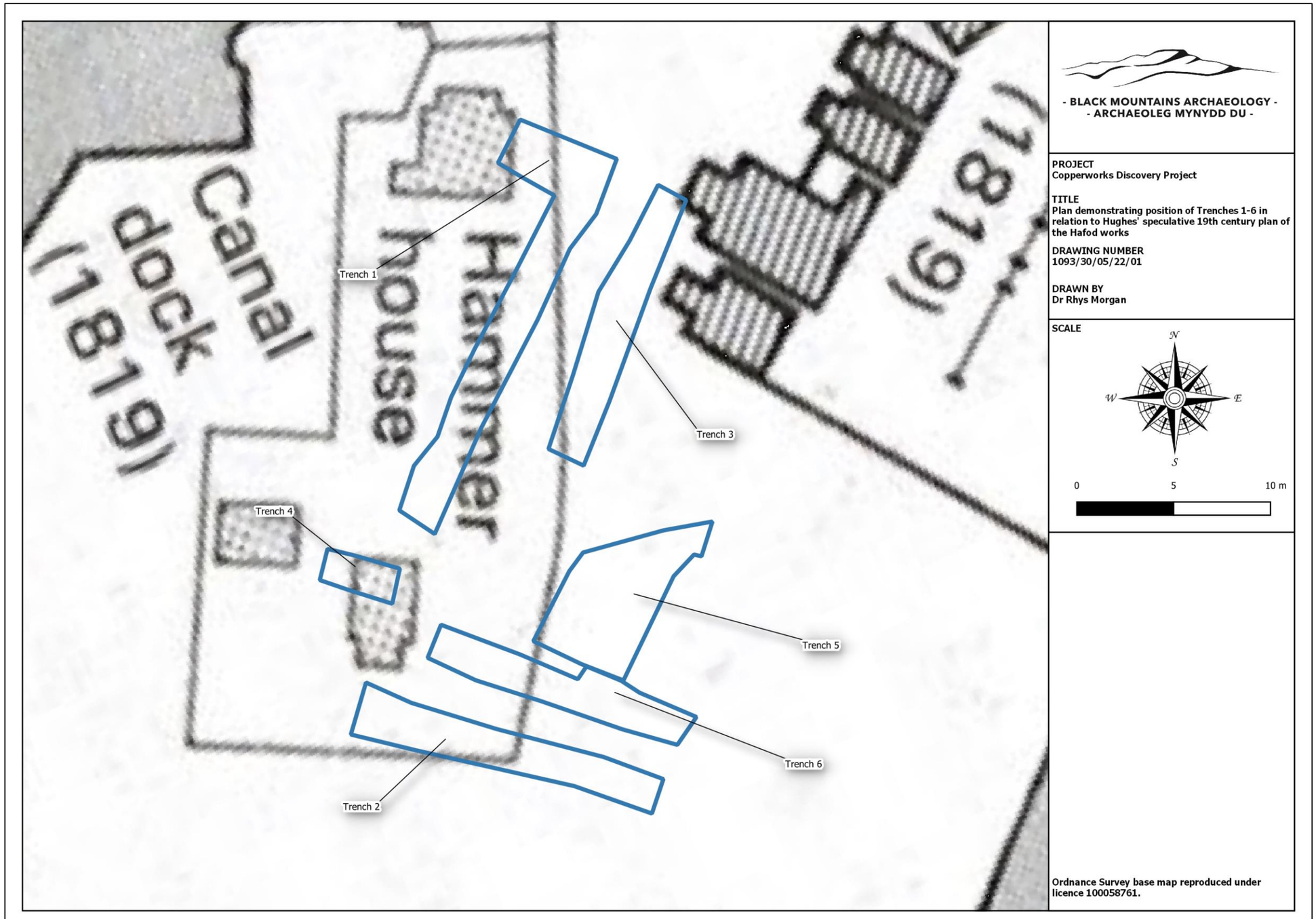
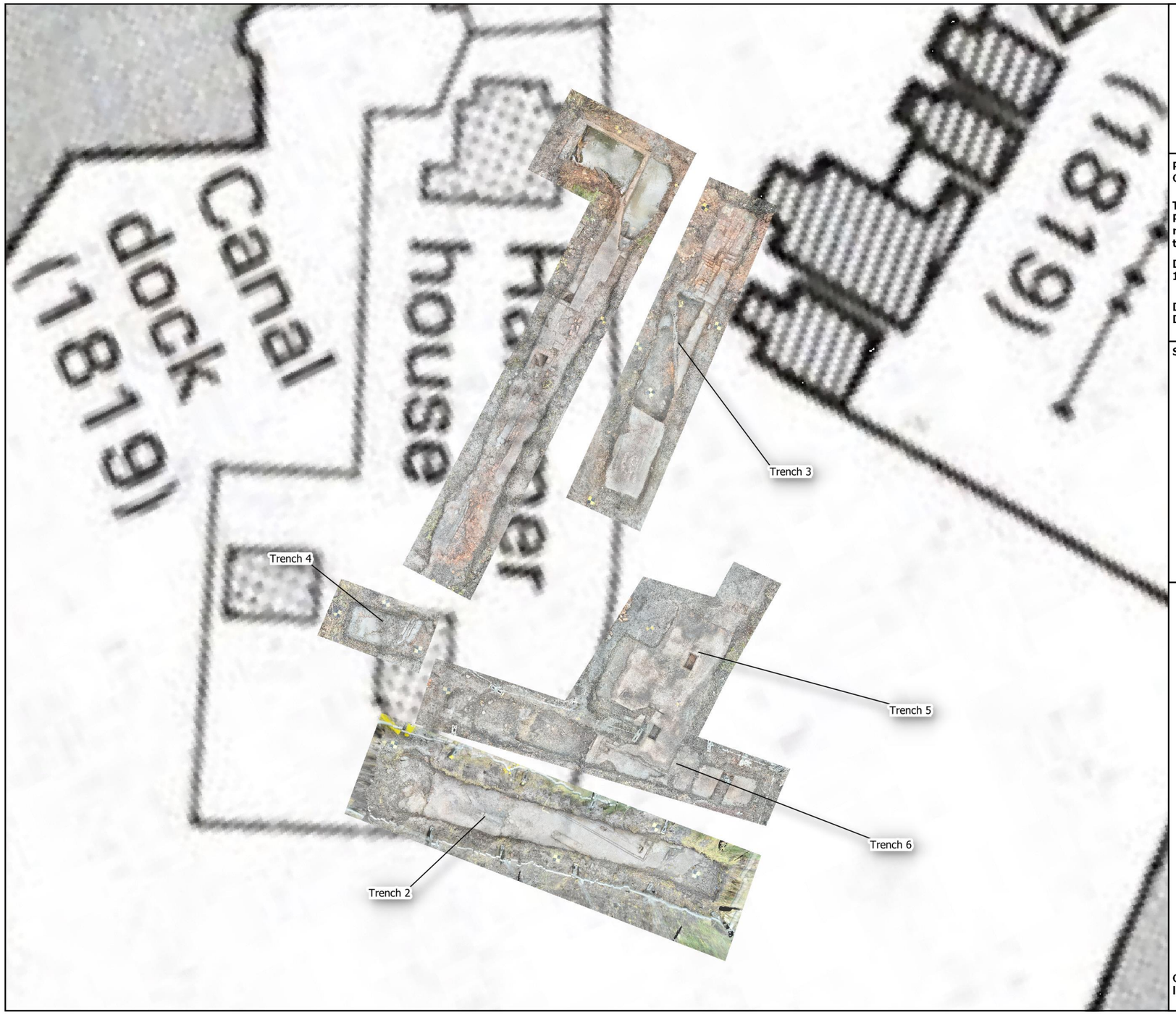


Figure 12. Position of Trenches 1–6 in relation to the speculative plan of the Hafod works from Hughes (2000) (reproduced with kind permission of RCAHMW)



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TITLE
Plan demonstrating position of Trenches 1-6 in relation to Hughes' speculative 19th century plan of the Hafod works (with photogrammetric stills)

DRAWING NUMBER
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SCALE

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Figure 13. Position of Trenches 1–6 in relation to the speculative plan of the Hafod works from Hughes (2000) with photogrammetric stills (reproduced with kind permission of RCAHMW)

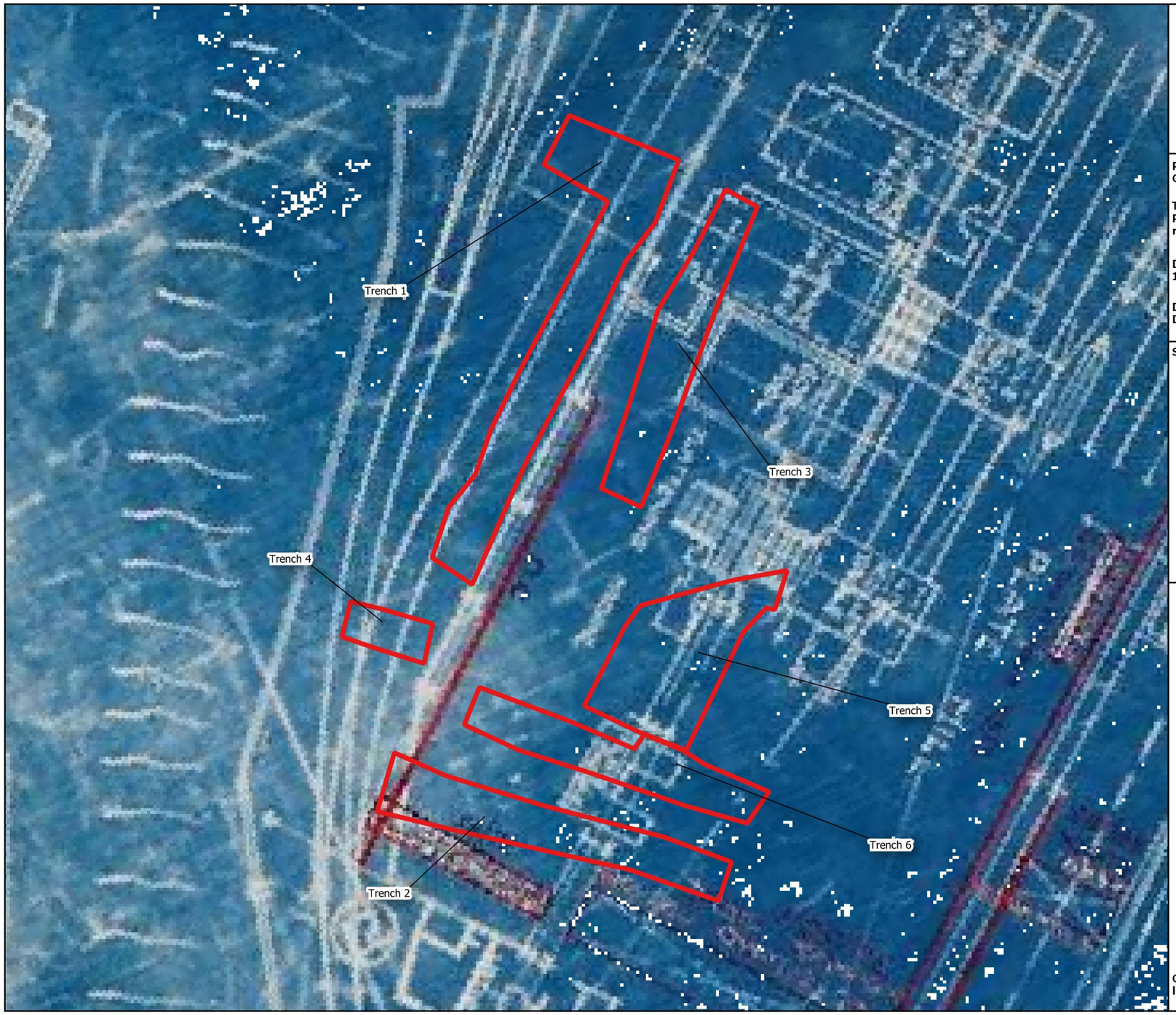

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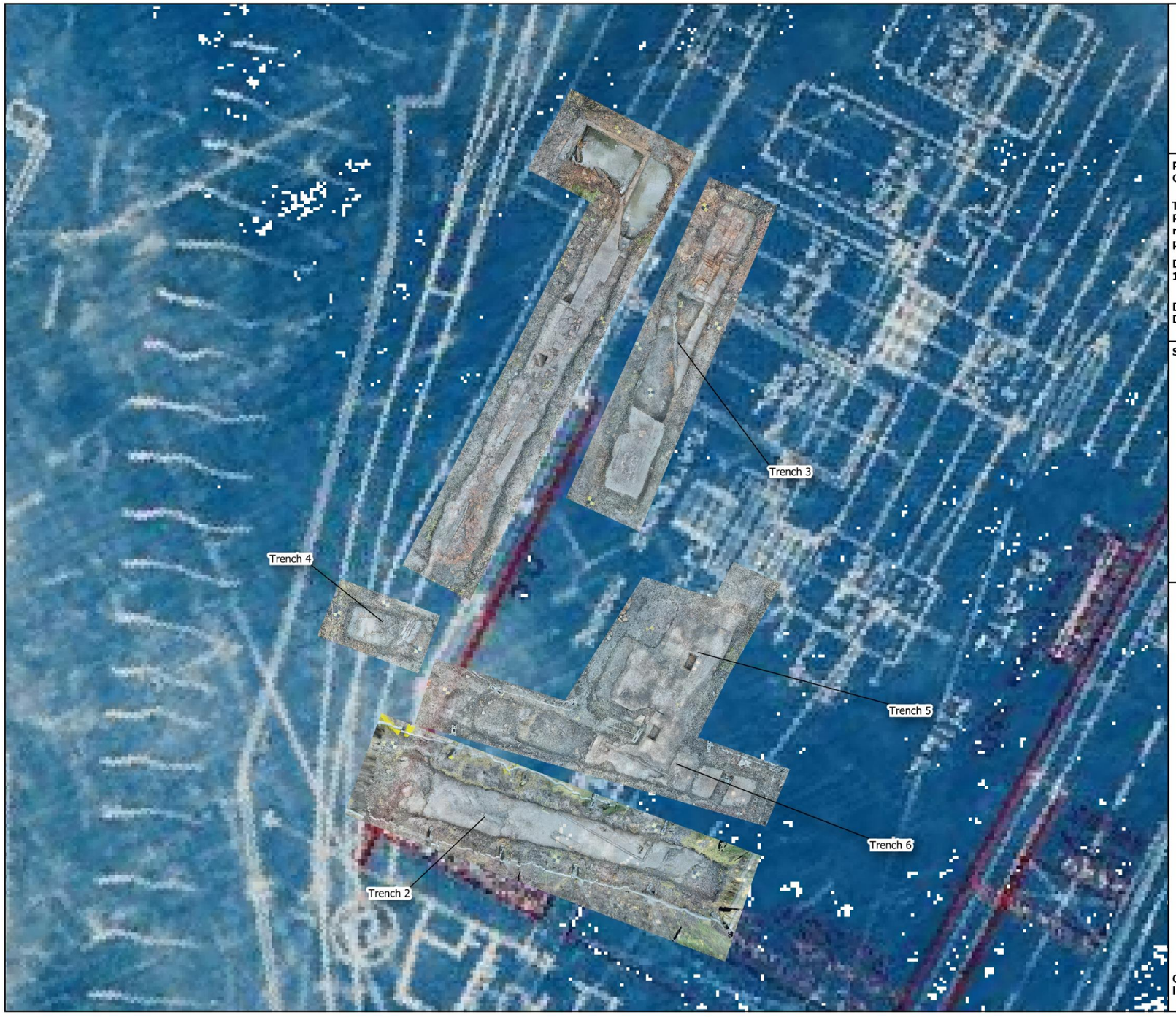
Figure 14. Position of Trenches 1–6 in relation to a 1939 plan of the Hafod works by ICI Metals Ltd with (© National Museum Wales)



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Plan demonstrating position of Trenches 1-6 in relation to 1939 plan of the Hafod works, wit photogrammetric stills

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Figure 15. Position of Trenches 1–6 in relation to a 1939 plan of the Hafod works by ICI Metals Ltd with photogrammetric stills (© National Museum Wales)

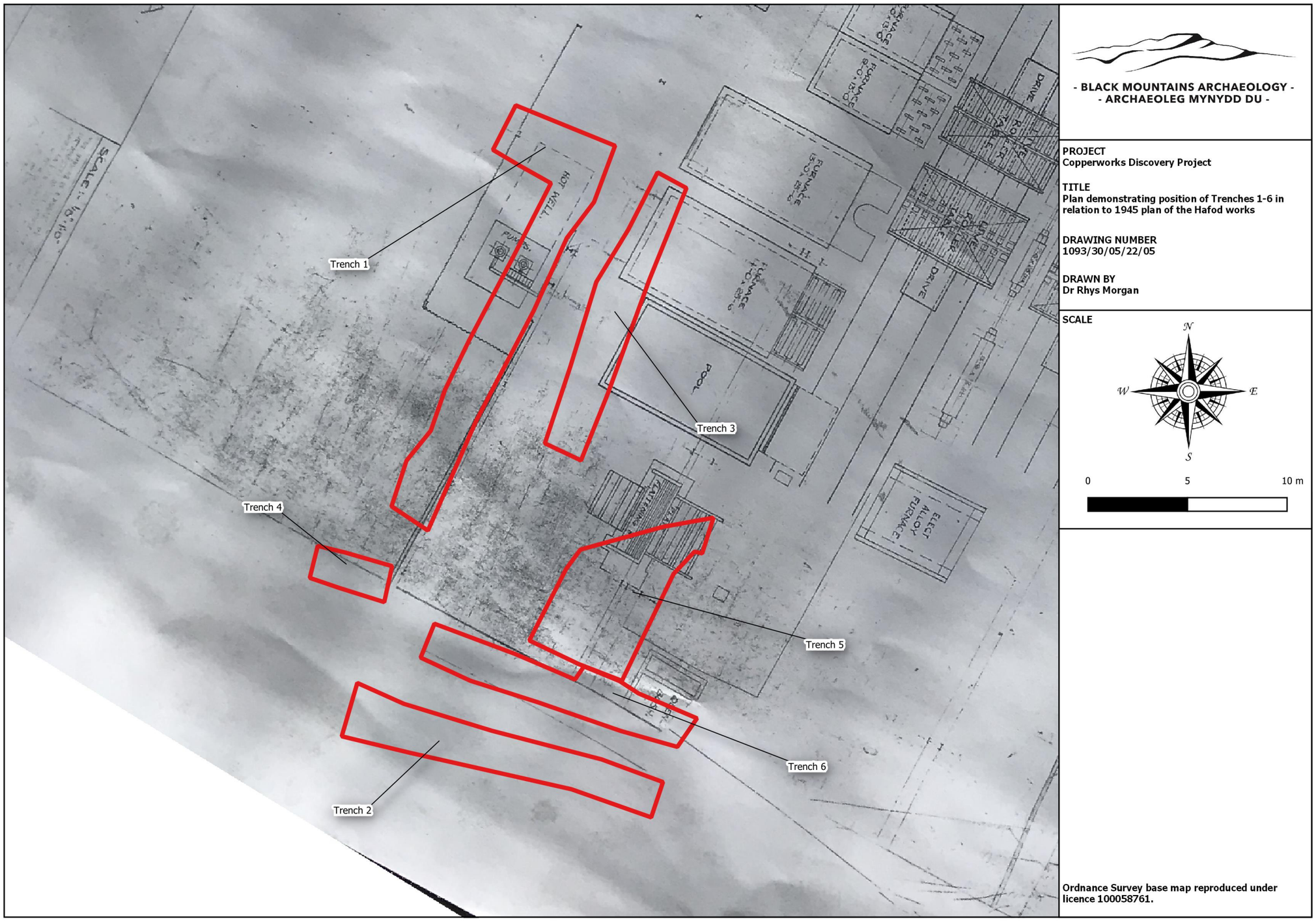

Figure 16. Position of Trenches 1–6 in relation to a 1945 plan of the Hafod works by ICI Metals Ltd (© City and County of Swansea)

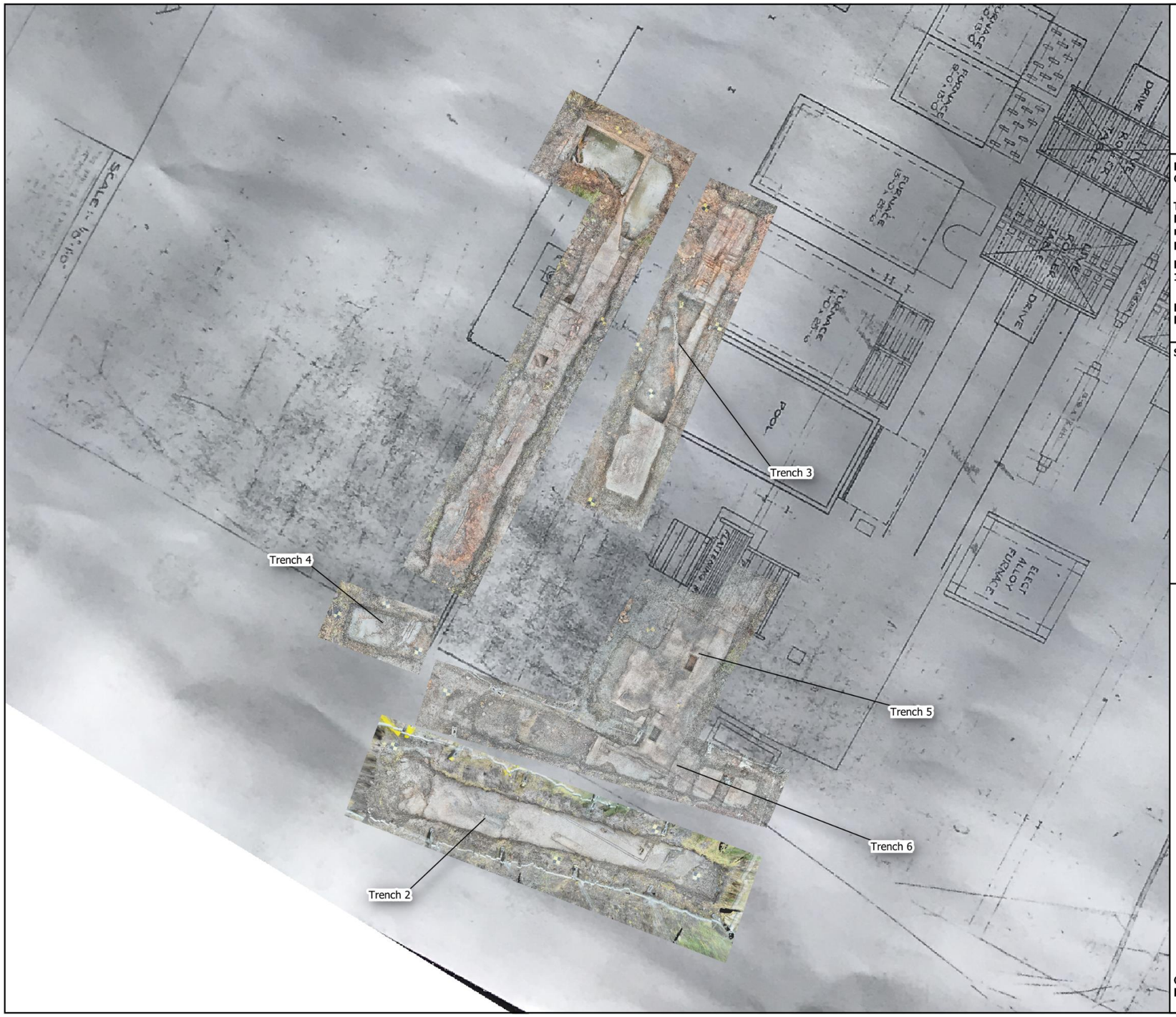

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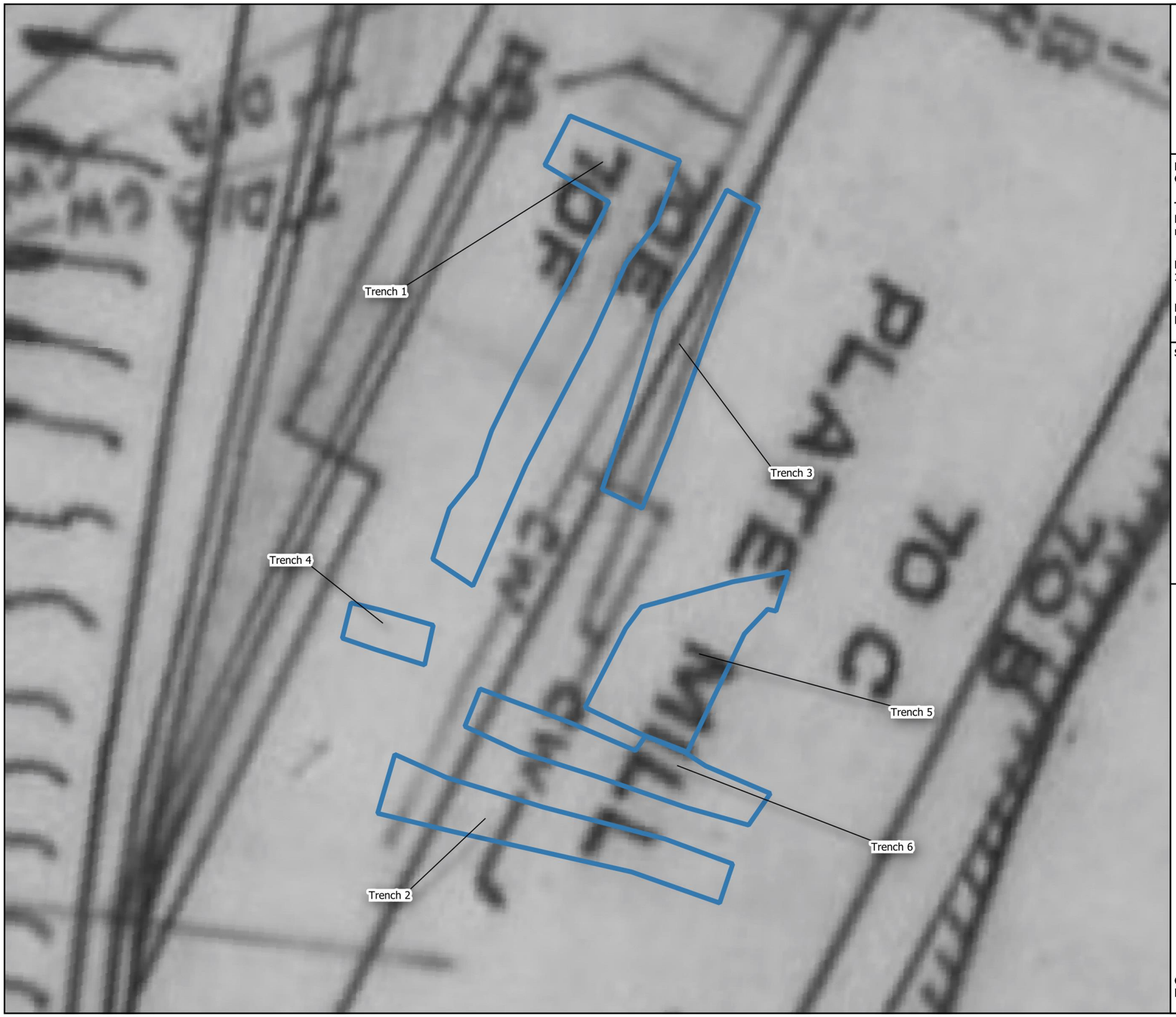
Figure 17. Position of Trenches 1–6 in relation to a 1945 plan of the Hafod works by ICI Metals Ltd with photogrammetric stills (© City and County of Swansea)



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TITLE
Plan demonstrating position of Trenches 1-6 in relation to 1951 plan of the Hafod works

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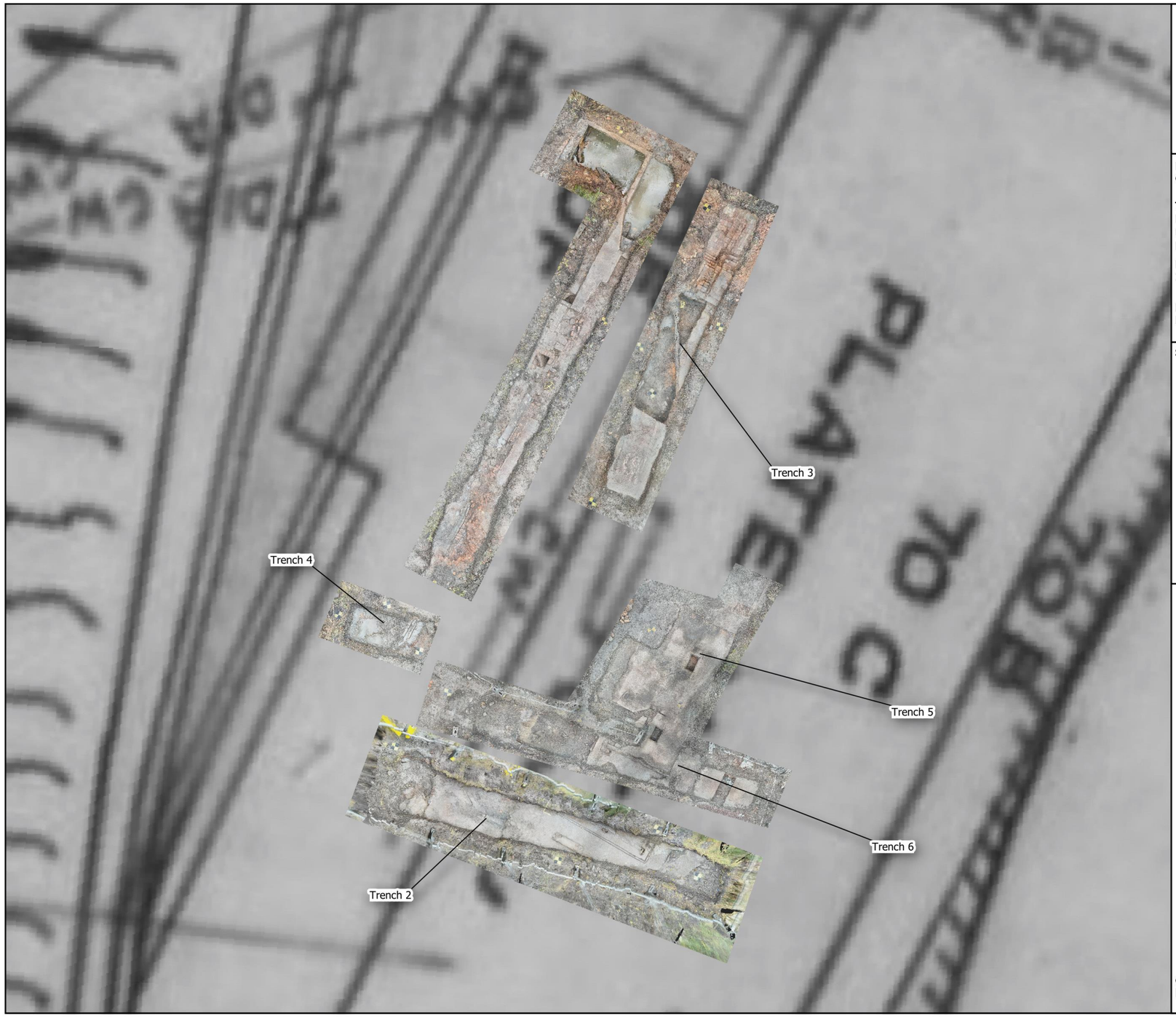
Figure 18. Position of Trenches 1–6 in relation to a 1951 plan of the Hafod works by ICI Metals Ltd (from photograph of original plan kindly provided by Swansea Museum Collections Centre)



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TITLE
Plan demonstrating position of Trenches 1-6 in relation to 1951 plan of the Hafod works, with photogrammetric stills

DRAWING NUMBER
1093/30/05/22/08

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Figure 19. Position of Trenches 1–6 in relation to a 1951 plan of the Hafod works by ICI Metals Ltd with photogrammetric stills (from photograph of original plan kindly provided by Swansea Museum Collections Centre)

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TITLE
Plan demonstrating position of Trenches 1-6 in relation to secnd 1951 plan of the Hafod works

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Figure 20. Position of Trenches 1–6 in relation to a second 1951 plan of the Hafod works by ICI Metals Ltd (© City and County of Swansea)

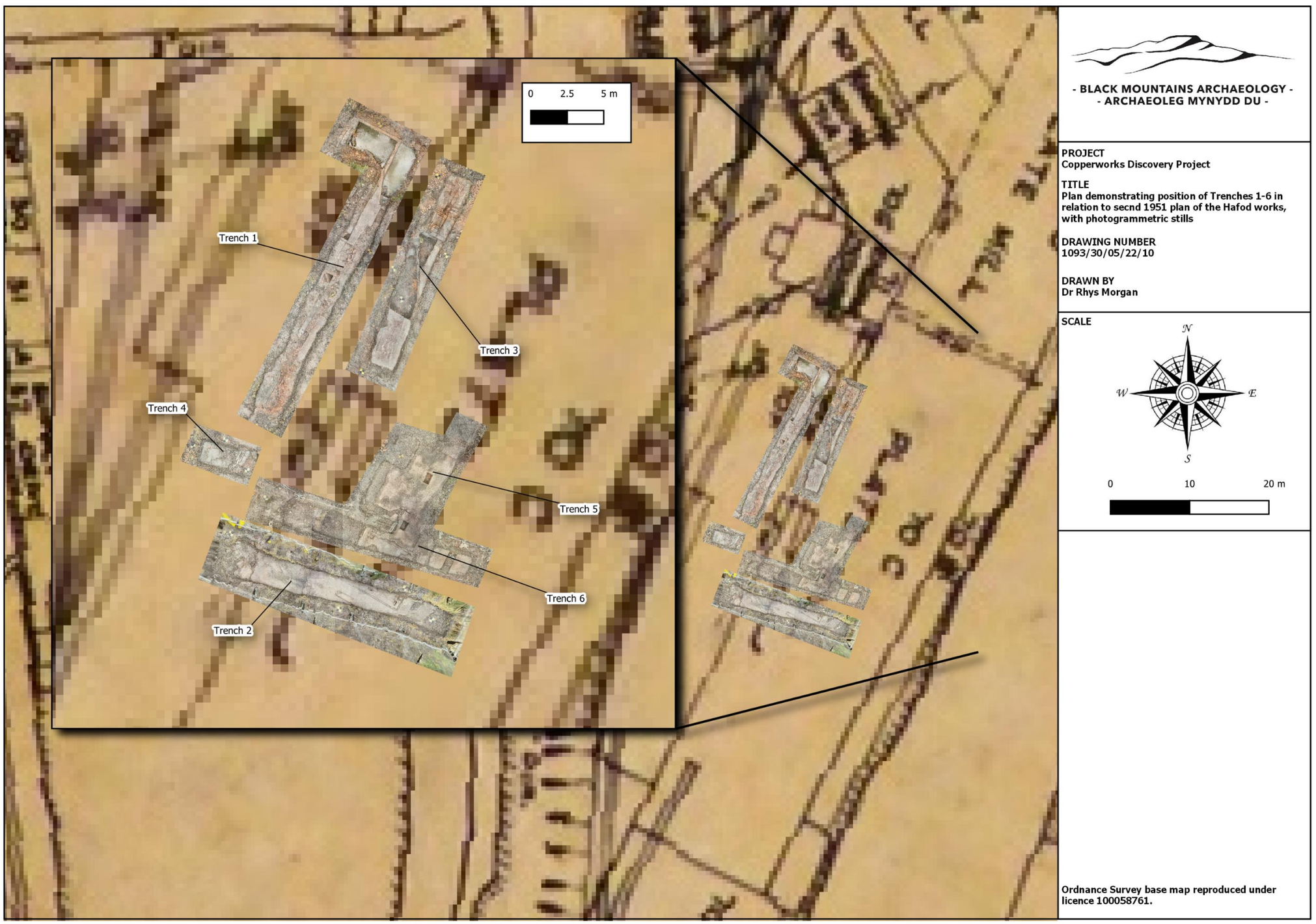

Figure 21. Position of Trenches 1–6 in relation to a second 1951 plan of the Hafod works by ICI Metals Ltd with photogrammetric stills (© City and County of Swansea)

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TITLE
Plan demonstrating position of Trenches 1-6 in relation to 1926-51 plan of works

DRAWING NUMBER
1093/30/05/22/11

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SCALE

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Figure 22. Position of Trenches 1–6 in relation to a plan of the Hafod works by ICI Metals Ltd published between 1926-51 (© City and County of Swansea)

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TITLE
Plan demonstrating position of Trenches 1-6 in relation to 1926-51 plan of works, with photogrammetric stills

DRAWING NUMBER
1093/30/05/22/12

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Figure 23. Position of Trenches 1–6 in relation to a plan of the Hafod works by ICI Metals Ltd published between 1926-51 with photogrammetric stills (© City and County of Swansea)

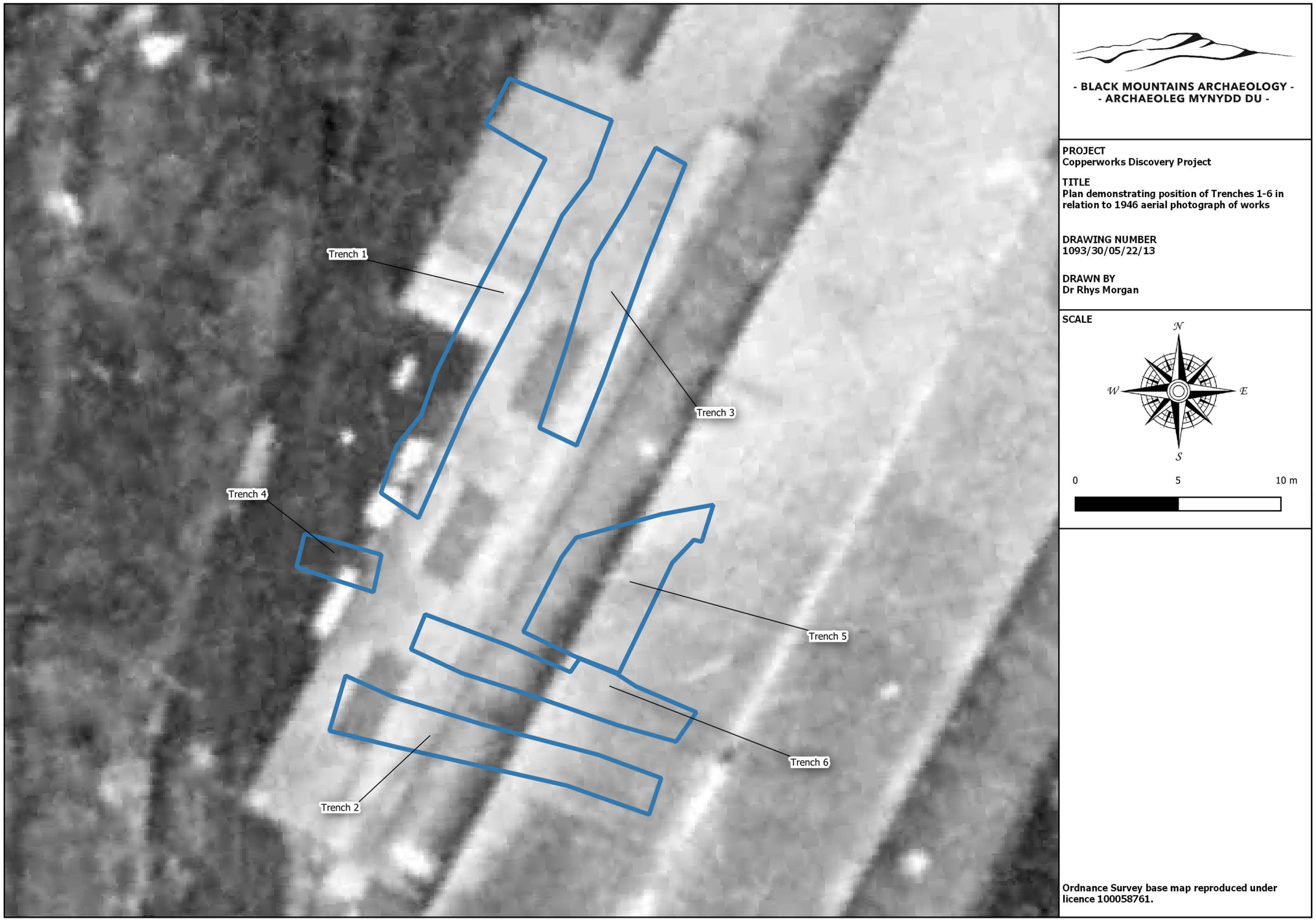

Figure 24. Position of Trenches 1–6 in relation to a 1946 aerial photograph taken by the RAF of the Hafod works (© Welsh Government)

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PROJECT
Copperworks Discovery Project

TITLE
Plan demonstrating position of Trenches 1-6 in relation to 1946 aerial photograph of works, with photogrammetric stills

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Figure 25. Position of Trenches 1–6 in relation to a 1946 aerial photograph taken by the RAF of the Hafod works with photogrammetric stills (© Welsh Government)

7.2 Appendix II – Plates

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Plate 1. northeast facing view of Trench 1

Plate 2. East facing (representative) section towards centre of Trench 1, showing demolition deposit (101)

Plate 3. Rubble spread (136) overlying wall [123] in Trench 1 (view east)

Plate 4. Wall [123], rubble spread (136) and drain [135] in Trench 1 (view southwest)

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Plate 12. Eastern wall of hot well [141] in Trench 1 (view east)

Plate 13. Northern wall of hot well [141] in Trench 1 (view east)

Plate 14. Northern wall of hot well [141] in Trench 1 (view north)

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Plate 16. West facing view of Trench 2

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Plate 21. Deposit (212) in Trench 2 (view east)

Plate 22. Foundation [215] in Trench 2 (view south)

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Plate 25. Drip gully [218] in Trench 2 (view northwest)

Plate 26. Overhead view of pin profiles [221] between bases [219] and [220] in Trench 2

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Plate 31. Southwest facing view of Trench 3

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Plate 33. Concrete [302] overlying deposit (326) in Trench 3 (view southwest)

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Plate 36. Pipe [303] and concrete deposits [306] and [304] in Trench 3 (view northeast)

Plate 37. Pipe [303] and concrete deposits [306] and [304] in Trench 3 (view northeast)

Plate 38. Concrete [304] in Trench 3 (view northeast)

Plate 39. Wall [311] and pitch (312) in Trench 3 (view northeast)

Plate 40. Southern edge of annealing furnace [318] in Trench 3, as represented by features [311] and [313]–[316] (view west)

Plate 41. Southern edge of annealing furnace [318] in Trench 3, as represented by features [311] and [313]–[316] (view southeast)

Plate 42. Base of annealing furnace [318] in Trench 3, as represented by feature [317] (view northwest)

Plate 43. Extent of annealing furnace [318] uncovered in Trench 3 (view southwest)

Plate 44. Oblique view of east facing section of Trench 3, demonstrating deposits (301) and (319)–(323) (view northwest)

Plate 45. Oblique view of east facing section of Trench 3, demonstrating deposits (301) and (319)–(323) (view southeast)

Plate 46. Oblique view of west facing section of Trench 3, demonstrating deposits (301), (334) and (325)

Plate 47. South facing view of Trench 5

Plate 48. East facing (representative) section of Trench 5 demonstrating demolition deposit (501)

Plate 49. Manhole [508] in Trench 5 (view south)

Plate 50. Manhole [508] in Trench 5 (view north)

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Plate 52. Eastern edge of machine base [504] and manhole [506] in Trench 5 (view south)

Plate 53. Manhole [506] and machine base [504] in Trench 5 (view west)

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Plate 56. Machine base [504] in context within Trench 5, with manhole [506] and concrete [503] immediately to the east (view east)

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Plate 58. Rail [510] and manhole [509] on northeast edge of Trench 5 (view south)

Plate 59. East facing view of Trench 6

Plate 60. South facing (representative) section of Trench 6, demonstrating demolition deposit (601) and organ horizons (602) and (604)

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Plate 64. Western edge of concrete surface [614] within Trench 6 (view east)

Plate 65. Machine base [615] set within concrete [614] in Trench 6 (view east)

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Plate 67. Machine base [615] and concrete surfaces [619] and [620] in Trench 6 after its merging with Trench 5, with manhole [506] at bottom-right (view southeast)

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Plate 69. Feature [617] in Trench 6 (view east)

Plate 70. Feature [617] in Trench 6 (view west)

Plate 71. Feature [617] with view of fill (618) in Trench 6 (view south)

Plate 72. Close-up view of notches within southern edge of Feature [617] in Trench 6 (view southeast)

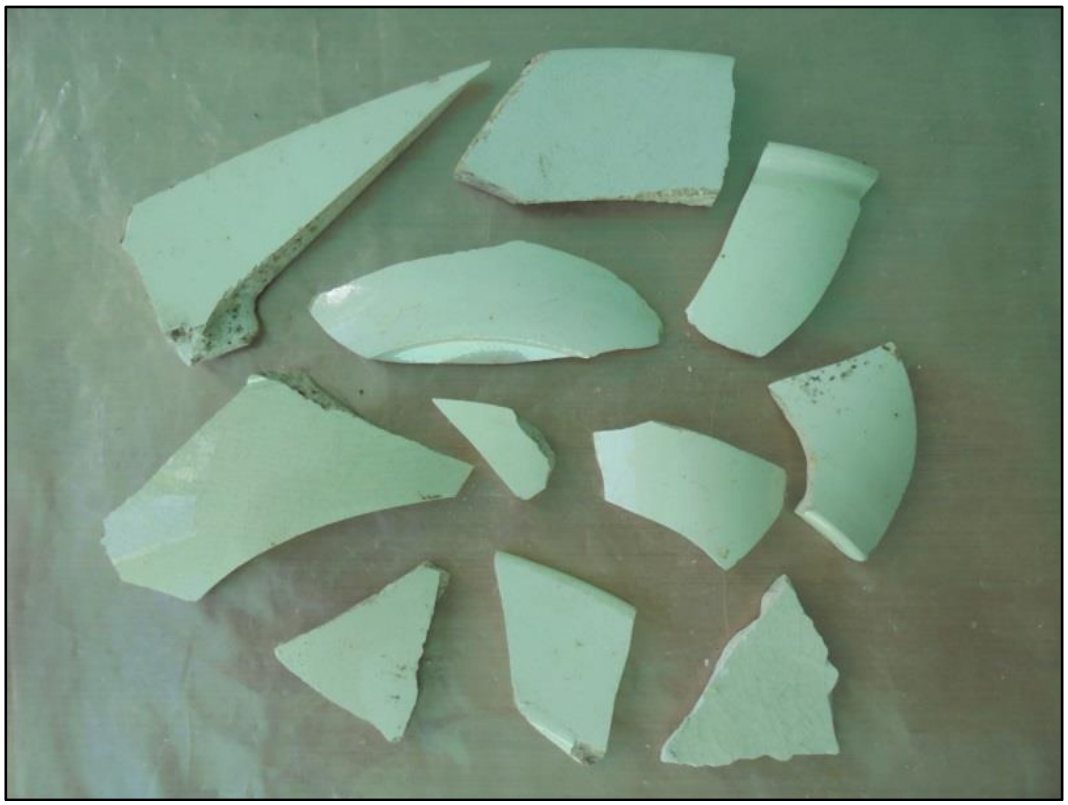

Plate 73. A representative sample of the undecorated earthenware from context 321

Plate 74. Creamware sherds with marble slip decoration, also known as 'dip ware' (context 321)

Plate 75. Pearlware plate sherds with blue feather or shell edging (context 321)

Plate 76. Hand-painted cup and saucer sherds (context 321; the saucer rim edge is missing)

Plate 77. Hand-painted saucer rim sherd with ochre bud decoration and ochre line along the rim (context 321)

Plate 78. A selection of blue transfer-printed sherds from context 321

Plate 79. Transfer-printed joining dish or bowl rim sherds (context 001)

Plate 80. Biscuit-fired sherds from context 321

Plate 81. Glazed cockspurs (context 321)

Plate 82. Glazed plate support and slilt fragments (context 321)

Plate 83. Unglazed kiln support and slilt fragments (context 321)

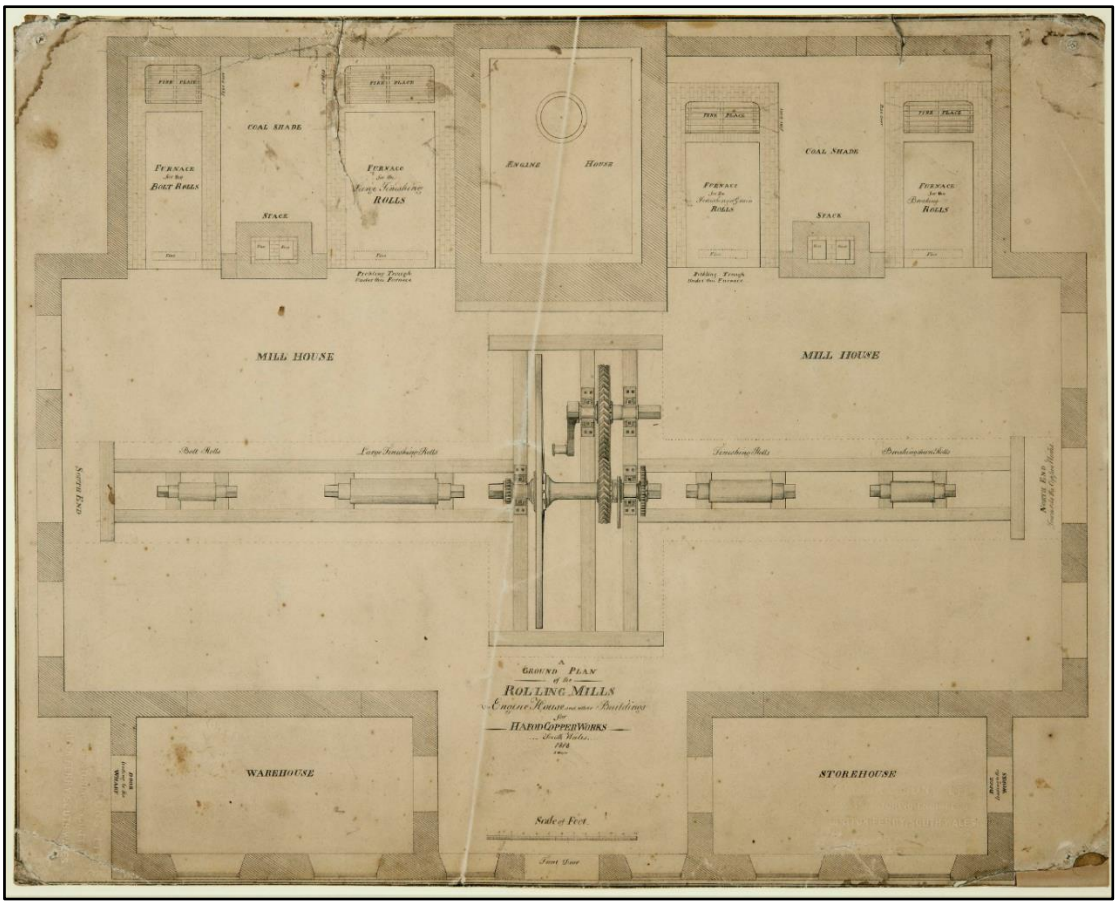

Plate 84. 1818 plan of the interior of the No 1 Rolling Mill, Hafod (copyright West Glamorgan Archives)

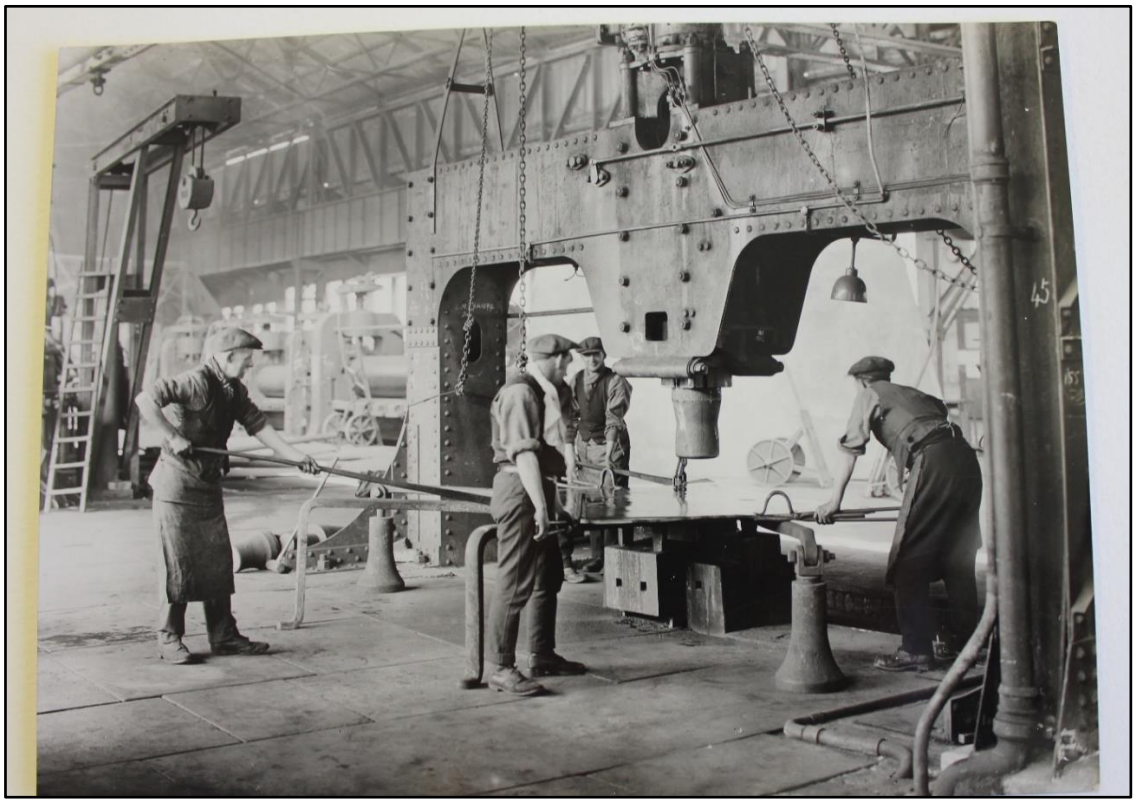

Plate 85. 20th century photograph of interior of Hafod Plate Rolling Mill, possibly depicting the plate flattening machine in operation (copyright West Glamorgan Archives)

Plate 86. 20th century photograph depicting the line of operations within the Hafod Plate Mill (copyright West Glamorgan Archives)

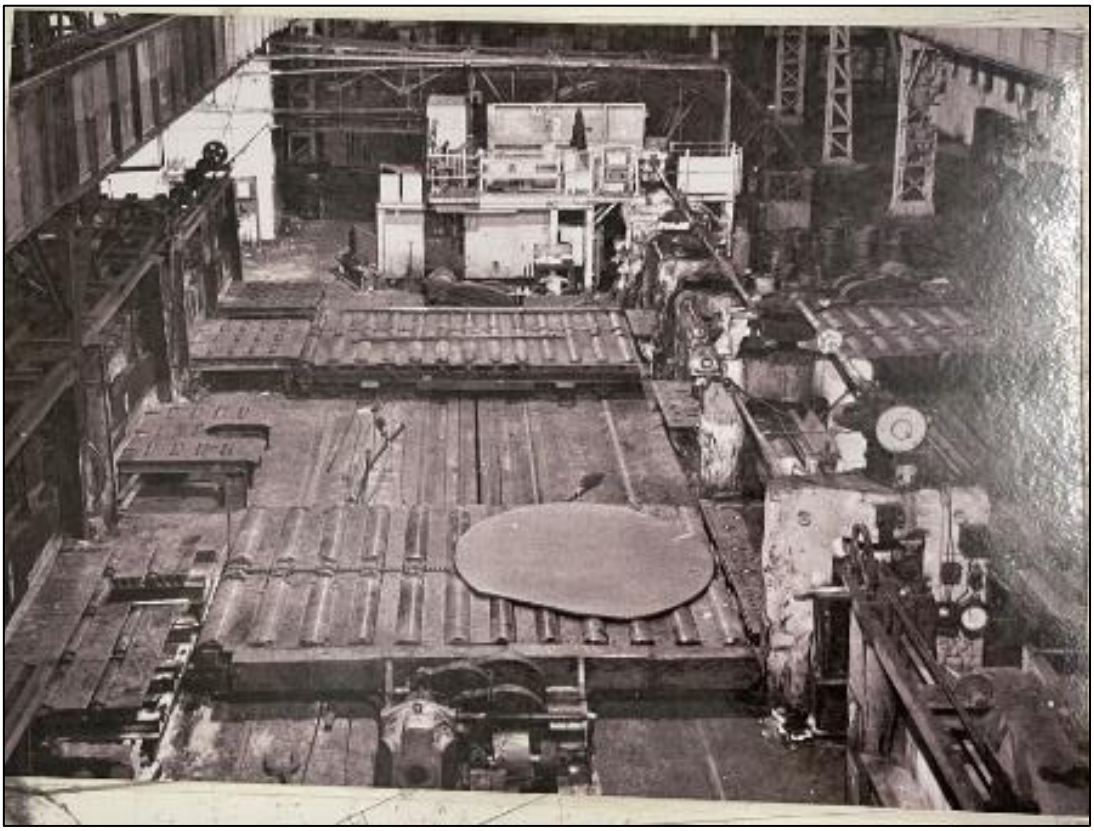

Plate 87. 20th century photograph of the interior of the Hafod Plate Mill, with rolls and annealing furnaces

Plate 88. 1971 photograph of annealing furnace within the Hafod Plate Mill

Plate 89. Proposal 2248 April 28th, 1910, showing position of original boiler range, near foot of remaining octagonal based chimney (copyright Swansea Museum)

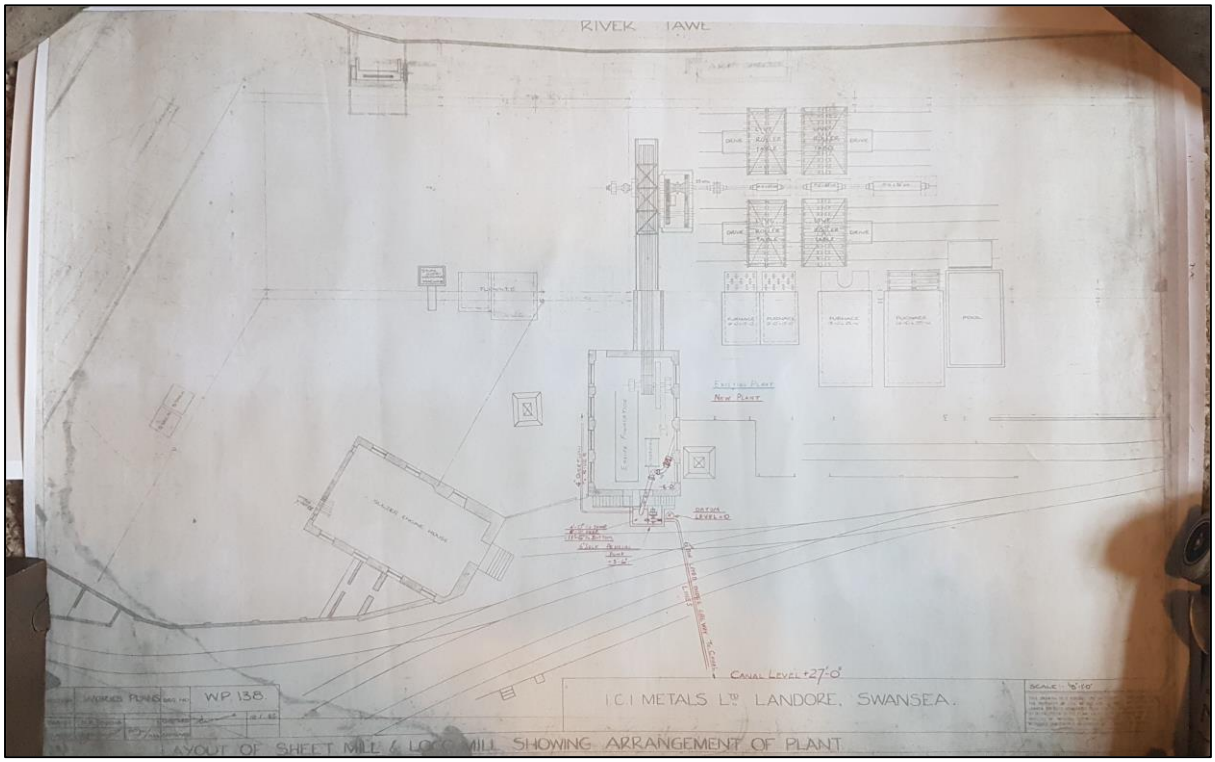

Plate 90. 1945 plan of Hafod works by ICI Metals showing proposed hot well (copyright Swansea Museum)

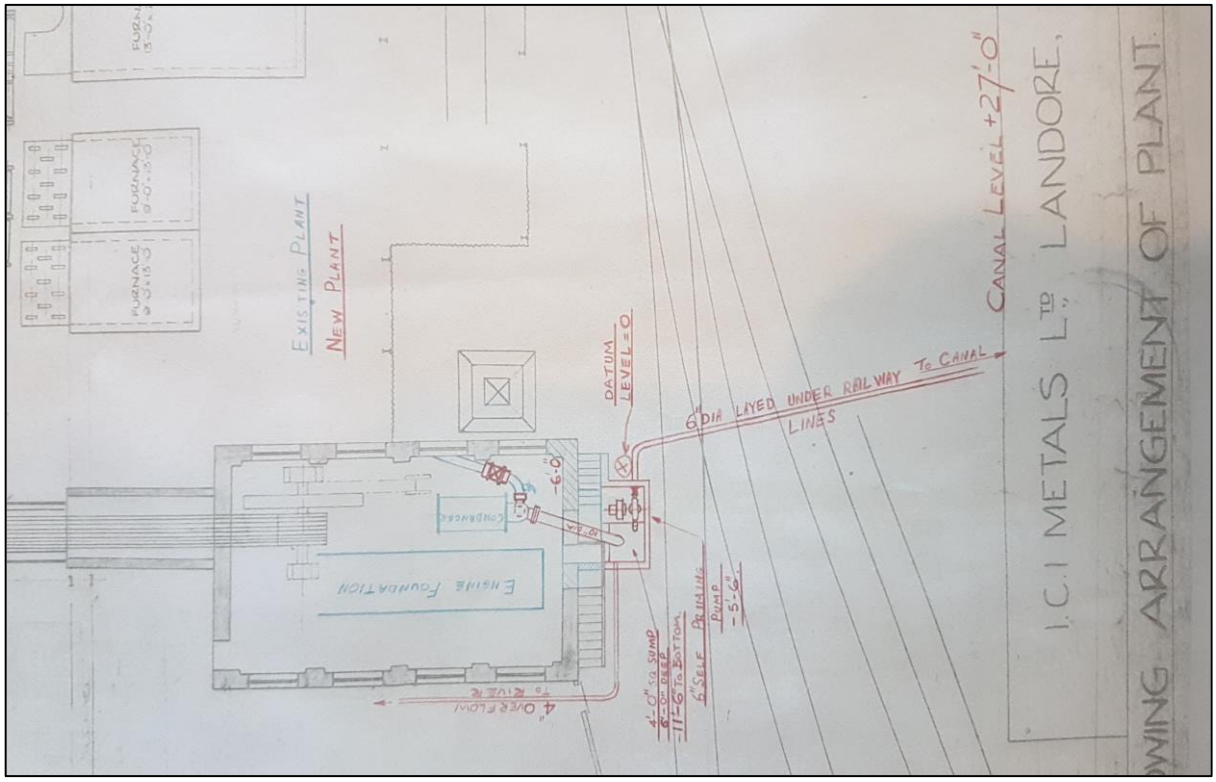

Plate 91. Close up of plan of Hafod works by ICI Metals showing proposed hot well (copyright Swansea Museum)

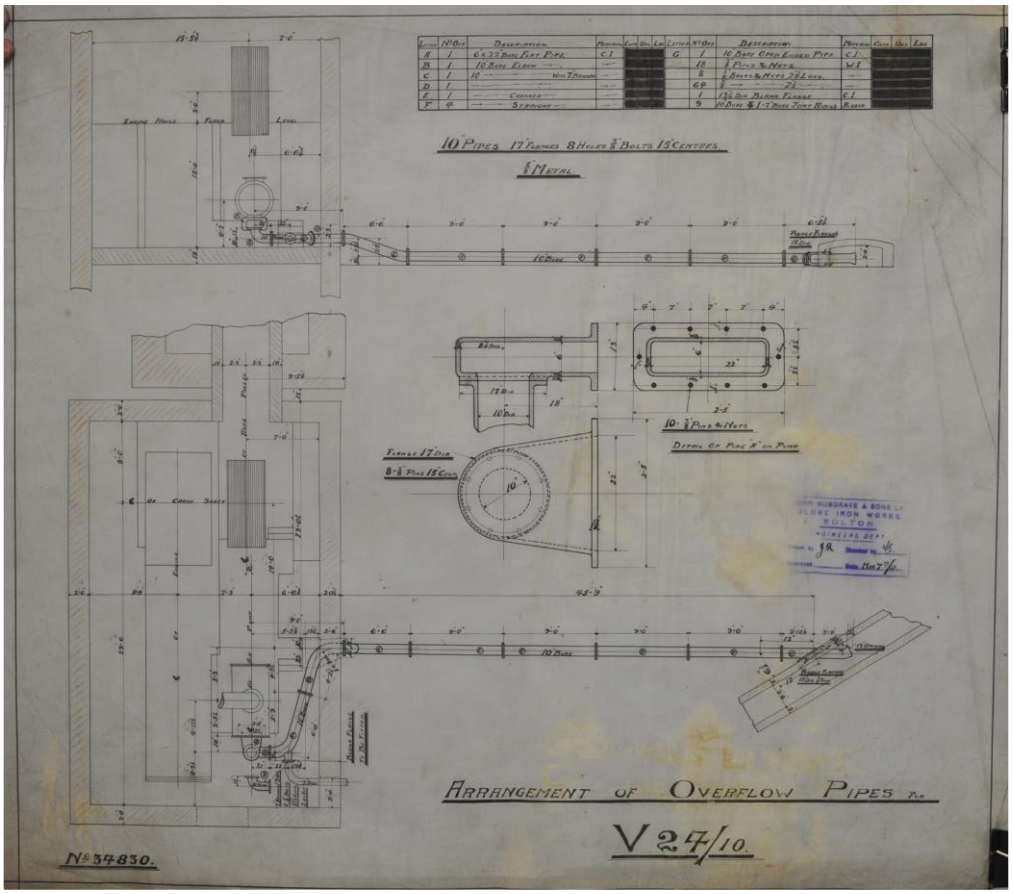

Plate 92. 1910 plan showing original outflow pipe of hot well (copyright Bolton Archives)

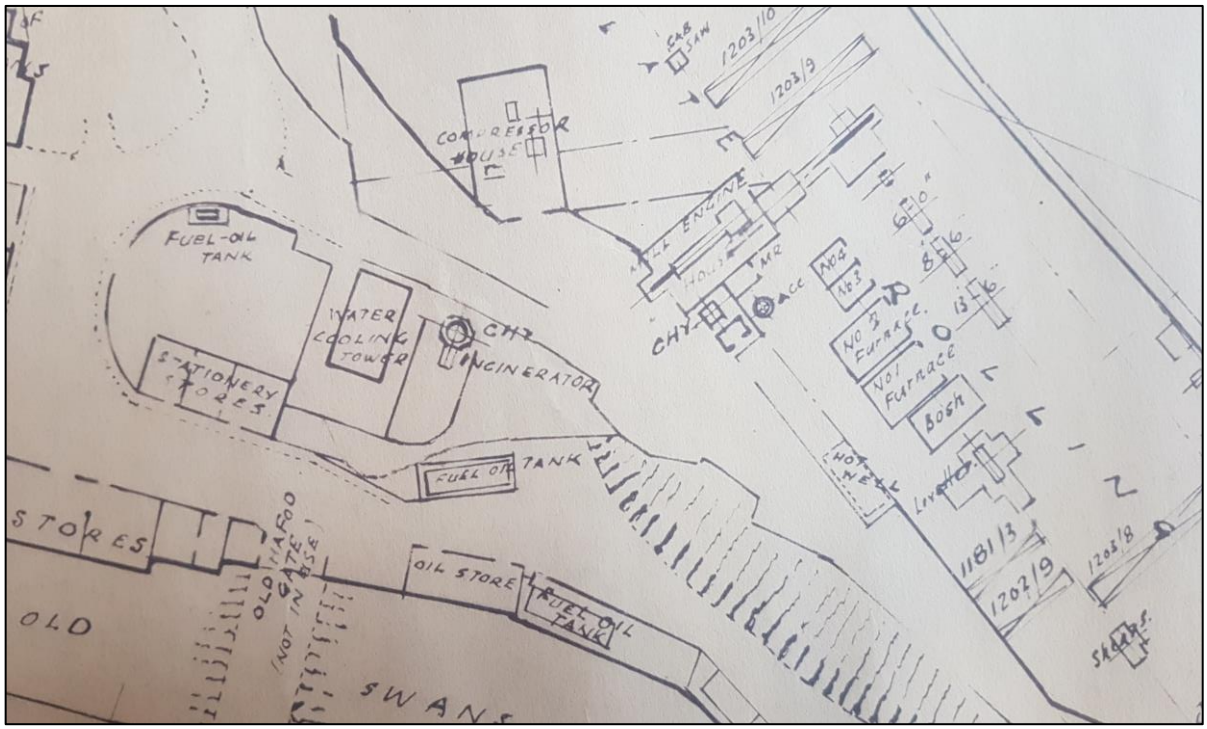

Plate 93. Close up of 1975 plan of Hafod works showing positions of hot well and cooling tower (copyright Swansea Museum)

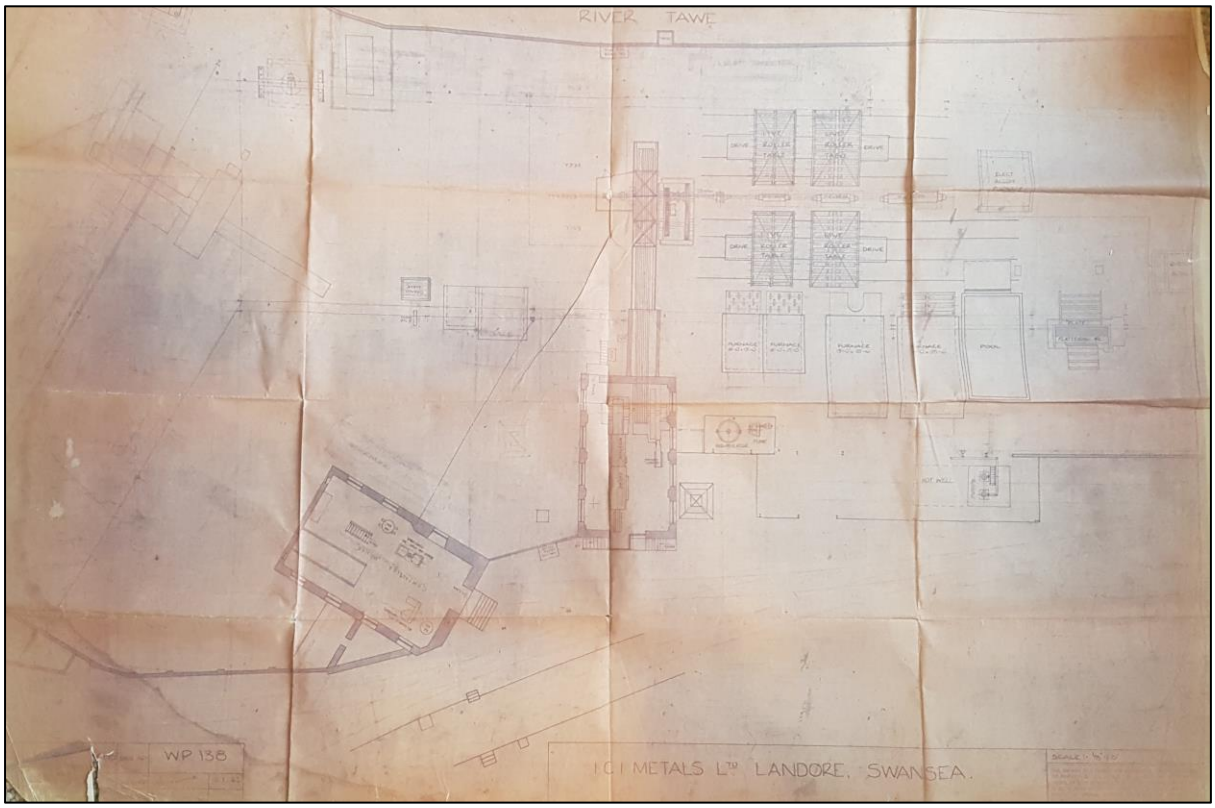

Plate 94. 1945 plan of Hafod works by ICI Metals showing hot well in final form (copyright Swansea Museum)

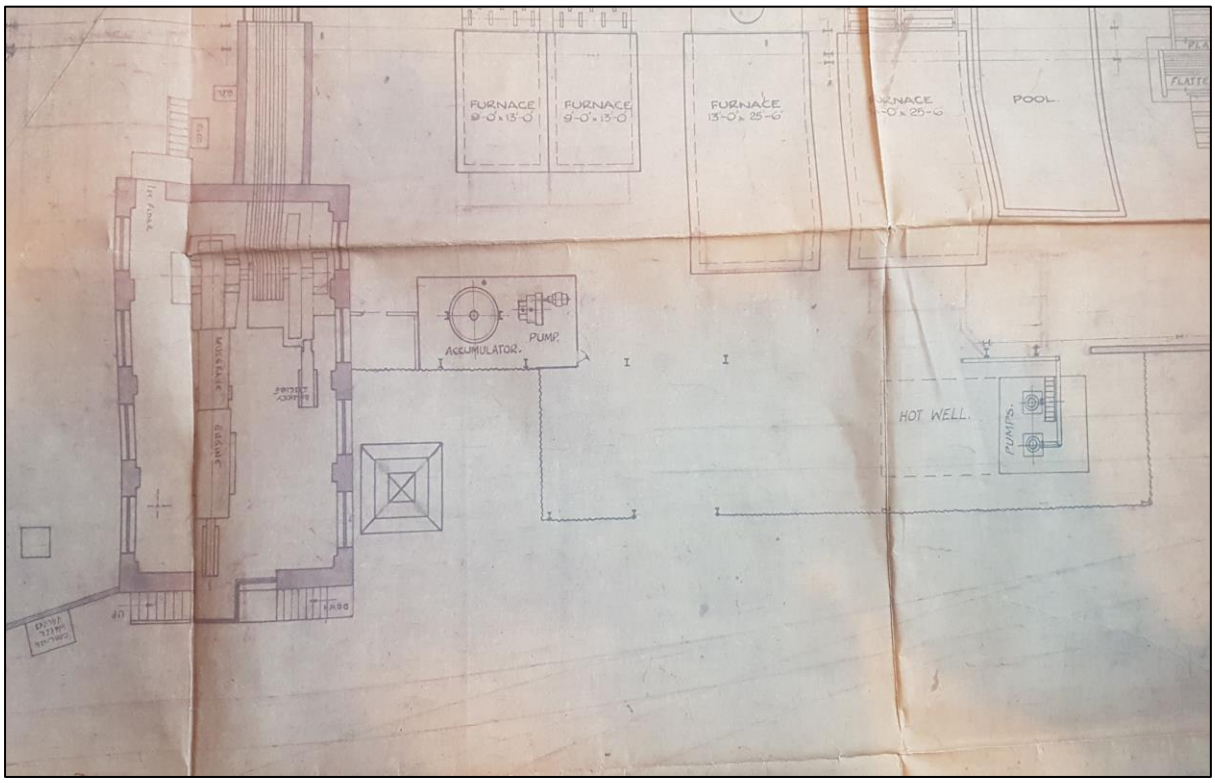

Plate 95. First close up of 1945 plan of Hafod works by ICI Metals showing hot well in final form (copyright Swansea Museum)

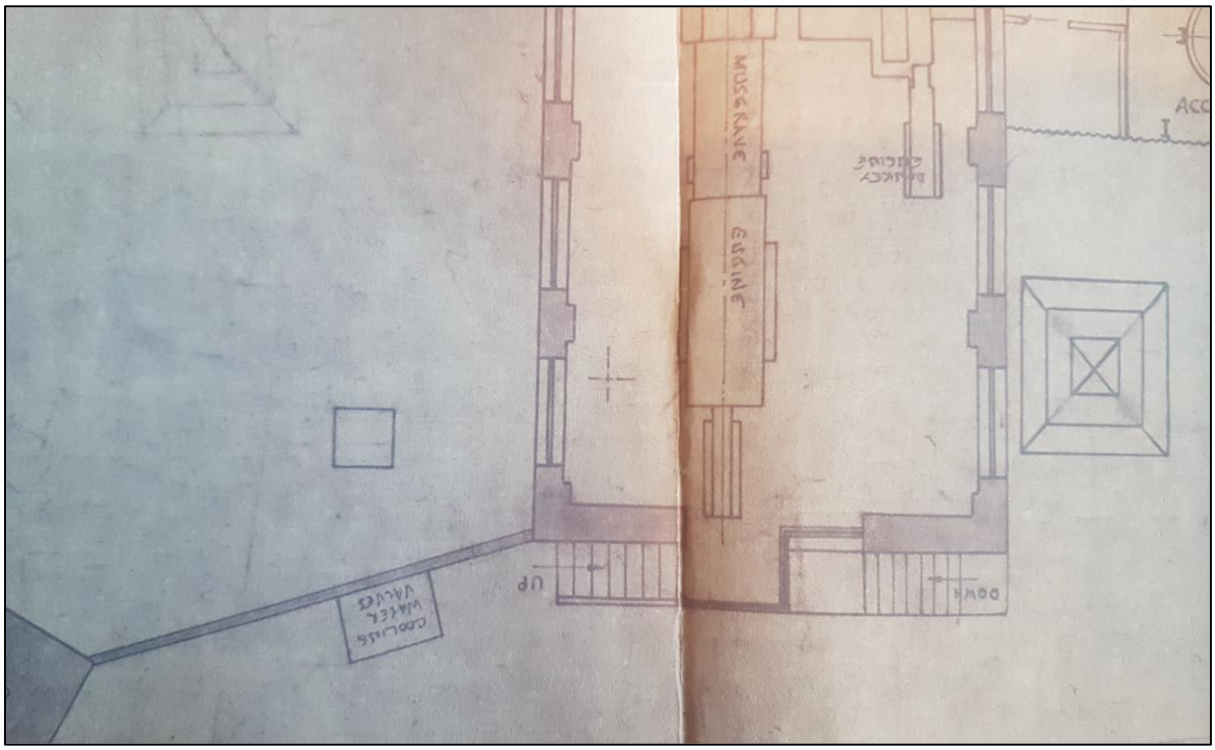

Plate 96. Second close up of 1945 plan of Hafod works by ICI Metals showing hot well in final form (copyright Swansea Museum)

Plate 97. *c* 1980 photograph of Musgrave Engine House after closure of Hafod-Morfa Copperworks, showing cooling tower pipes and condenser feed pipe running around base of chimney (copyright Swansea Museum)

7.3 Appendix III – Context Inventory

The entirety of the study area was covered by a thick demolition deposit which contained, most notably, masonry, brick, metal, and concrete in a dark brown silty clay matrix. Within each trench, this demolition deposit has been assigned a context number specific to the trench. In Trench 1 it is known as (101); in Trench 2 it is known as (201); in Trench 3 it is known as (301); in Trench 4 it is known as (401); in Trench 5 it is known as (501); and in Trench 6 it is known as (601). However, a general number has also been given to this deposit, which is detailed below.

Context	Type	Depth/Dimensions	Description	Period
001	Deposit	0.1–0.9m deep	Demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix. Glass bottle or jar base and sherd of transfer-printed ware discovered within.	Modern

Trench 1

Trench 1 was NE/SW aligned. The trench was linear in form, measuring 21.3m in length x 2.2m in width with a westward extension measuring 3.4m x 2.8m at its northern end. The height at the top of the trench was recorded at 7.1mOD at its south-western end and 6.94mOD at its north-eastern. The height at the base of the trench varied significantly. At the southwest end of the trench the base measured 6.9m. The base of excavations at the northeast end was not determined due to flooding, although the height at which the flood water levelled off was recorded at approximately 6.24mOD. With the aid of an extendable staff, the base of the hot well was determined to be approximately 2.5m deep, meaning that it was situated at around 4.44mOD. In total, the area covered by Trench 1 was 54.86m^2. The average depth of excavation was 0.6m.

Context	Type	Depth/Dimensions	Description	Period
101	Deposit	0.3–0.9m deep	Demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix.	Modern
102	Structure	>2.5m deep	Concrete that formed hot well [141] and pump chamber [142].	Modern
103	Structure	Unknown	Inlet pipe, cast iron, running into hot well [141] from north.	Modern
104	Structure	Unknown	Outlet pipe, cast iron, running from hot well [141] to east.	Modern
105	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on south of western wall of hot well [141].	Modern
106	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on north of western wall of hot well [141].	Modern
107	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on north of eastern wall of hot well [141].	Modern

108	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on north of eastern wall of hot well [141].	Modern
109	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on south of eastern wall of hot well [141].	Modern
110	Structure	0.15m x 0.18m x 0.17m deep	Notch for RSJ, set within concrete [102], on south of eastern wall of hot well [141].	Modern
111	Structure	0.7m wide x at least 0.85m long	Concrete covering pipe [104] on exterior (east) of hot well [141].	Modern
112	Structure	0.83m wide x *c* 0.02m thick	Steel cover for possible access chamber into pipe [104].	Modern
113	Structure	0.64m long x 0.3m wide x 0.54m deep	Western side wall of culvert [115]. Concrete.	Modern
114	Structure	0.54m long x 0.56m wide x 0.26m deep	Lintel topping culvert [115]. Composed of pair of bricks.	Modern
115	Structure	0.57m deep	Culvert, *c* NE/SW aligned, runs beyond eastern edge of hot well [141] and pump chamber [142].	Modern
116	Structure	Unknown	Eastern side wall of culvert [115]. Concrete. Almost completely destroyed.	Modern
117	Deposit	>0.5m wide x 0.3m deep	Fill of culvert [115]. Black silt with frequent amounts of clinker and oil/pitch throughout.	Modern
118	Structure	Unknown	Steel plate topping a small cavity to east of hot well [141]. Possible lintel for drain.	Modern
119	Structure	Unknown	Steel shutter on southwest edge of concrete [111].	Modern
120	Structure	0.25m long x 0.15m wide	RSJ set within concrete [102]. Formed vertical member within wall [123].	Modern
121	Structure	0.45m diameter	Base of possible rail leading into pump chamber [142] from east.	Modern
122	Structure	0.25m long x 0.15m wide	RSJ set within concrete [102]. Formed vertical member within wall [123].	Modern
123	Structure	0.24m wide x >14.3m long	West wall of plate rolling mill annex. Formed of modern and re-used 19th century bricks situated between RSJs (e.g. [120] and [122]).	Modern
124	Cut	0.1m wide	Cut within southern wall of pump chamber [142] to facilitate entry of electric cable. Cuts concrete [102].	Modern
125	Structure	0.1m deep	Concrete surface abutting western edge of wall [123].	Modern
126	Structure	0.4m x 0.32m x 0.1m deep	Possible repair to surface [125]. Formed of concrete infilled slab.	Modern
127	Cut	0.1m deep	Cut in concrete floor [125] leading up to and connecting with cut [124].	Modern

128	Deposit	Unknown	Small deposit of sand, yellow in colour, between concrete [126] and manhole [129].	Modern
129	Structure	0.24m x 0.11m x >0.07m deep	Manhole. Formed of frogged and stamped bricks.	Modern
130	Structure	c 0.16m thick	Possible cover of manhole [129]. Formed of highly fragmented concrete.	Modern
131	Structure	0.07m wide x *c* 1.16m long	Single line of tiles (CBM) running along eastern edge of manhole [129]. Yellow in colour, unfrogged and poorly fired.	Modern
132	Structure	1.35m x 1m	Demolition deposit. Composed of broken concrete slabs.	Modern
133	Structure	0.33m wide	Concrete drainage gully running along western edge of wall [123].	Modern
134	Structure	Unknown	Interior floor of plate rolling mill annex. Formed of concrete. Abuts wall [123] on its eastern edge.	Modern
135	Structure	0.39m wide	Concrete drainage gully running along western edge of wall [123].	Modern
136	Deposit	*c* 1m wide x 3.7m long x *c* 0.1m deep	Rubble deposit, composed of degraded red brick, on east side of wall [123]. Possible remains of wall [123].	Modern
137	Structure	0.45m diameter	Base of possible rail leading into pump chamber [142] from east.	Modern
138	Deposit	*c* 2.5m deep	Fill of hot well [141]. Identical to (101) aside from inclusion of large sections of plastic pipe	Modern
139	Structure	0.25m wide	Concrete skirting on west and east sides of concrete [125] and [126]. Overlying sand deposit (128).	Modern
140	Structure	>0.5m 0.2m wide	Possible southern wall of hot well [141].	Modern
141	Structure	*c* 2.5m deep	Hot well. Formed of concrete [102].	Modern
142	Structure	Unknown	Pump chamber attached to southwest side of hot well [141]. Formed of concrete [102].	Modern
143	Structure	Unknown	Concrete floor situated between culvert [115] and concrete covering [111]. Only momentarily observed due to flooding.	Modern
144	Cut	1.35m x 1m?	Potential wall foundation running E/W. Possibly infilled with deposit (132).	Modern
145	Deposit	*C* 1m x 0.9m	Mixture of ash and soil, not excavated due to health and safety reasons	Modern

Trench 2

Trench 2 was broadly E/W aligned. The trench measured 16.1m in length x 2.2m in width. The height at the top of the trench was recorded at 7.04mOD at its western end and 7.28mOD at its eastern. The height at the base of the trench was recorded at a uniform 6.56mOD. In total, the area covered by Trench 2 was 33.52m^2. The average depth of excavation was 0.64m.

Context	Type	Depth/Dimensions	Description	Period

201	Deposit	0.26–0.8m deep	Demolition material, most notable masonry, brick, metal and concrete in a dark brown silty clay matrix.	Modern
202	Deposit	0.09m deep	Deposit of clinker observed at west end of trench. Underlies (201). Overlies concrete [203].	Modern
203	Structure	>1.2m x 1.1m	Concrete sub-base underlying floor of plate rolling mill annex. Partly underlies clinker (202).	Modern
204	Structure	>0.7m x 0.1m x 0.07m thick	Timber plank set into concrete [203]. Unknown function.	Modern
205	Structure	0.4m x 0.3m	Base of timber post. Abutted by concrete [203].	Modern
206	Structure	0.09m deep	Concrete floor of plate rolling mill annex. Overlies sub-base [203].	Modern
207	Structure	>0.17m x >0.29m x 0.1m deep	Foundation set into concrete [203]. Possible remains of vertical member associated with gantry crane. Alternatively, could be remains of machine base. Underlies (202).	Modern
208	Deposit	0.1m deep	Fill of foundation [207]. Clinker and re-deposited natural of mid-orangey brown silty clay.	Modern
209	Structure	0.9m long x 0.07m wide	Timber set into concrete [206]. N/S aligned.	Modern
210	Structure	0.98m long x 0.25m wide x >0.1m deep	Linear foundation set into concrete [203]. Infilled with [211]. Constitutes machine base or rail.	Modern
211	Structure	0.48m long x 0.25m wide x >0.1m deep	Concrete fill of foundation [210].	Modern
212	Deposit	0.1m deep	Fragments of clinker, brick and timber cemented together within a slag-rich matrix.	Modern
213	Structure	>2.1m long x 1.1m wide	Concrete floor surface overlying earlier concrete deposit [206].	Modern
214	Structure	0.12m deep	Concrete floor deposit. Possibly laid as replacement for concrete [214].	Modern
215	Structure	1.6m long x 0.39m wide	Linear concrete foundation of machine. NW/SE aligned.	Modern
216	Structure	0.24m long x 0.16m wide x >0.02m deep	Base of vertically set RSJ. Set into concrete [215].	Modern
217	Structure	0.24m long x 0.16m wide x >0.02m deep	Base of vertically set RSJ. Set into concrete [215].	Modern
218	Structure	0.11m wide x >4.8m	Drip gully. Forms part of [223].	Modern
219	Structure	0.16m wide x >2.7m long	Linear concrete foundation of machine. Oriented NW/SE. Forms part of [223].	Modern

220	Structure	0.16m wide >0.65m	Linear concrete foundation of machine. Oriented NE/SW. Forms part of [223].	Modern
221	Structure	Unknown	Remains of pair of pins (probably steel). Originally set between concrete [219] and [220]. No longer in-situ. Forms part of [223].	Modern
222	Structure	0.29m long x 0.02m wide x >0.03m deep	Steel plate. Forms part of [223].	Modern
223	Structure	>1.6m long	Remains of machine (shears). Comprises [218]–[222].	Modern
224	Deposit	0.2m deep	Re-deposited natural abutting south side of concrete [220]. Underlies rubble (201).	Modern
225	Structure	0.11m deep	Concrete surface underlying concrete [214].	Modern
226	Structure	0.1m deep	Concrete surface underlying concrete [215].	Modern
227	Deposit	c 0.04m deep	Deposit of slag and stone, red in colour, abutting east edge of concrete [214].	Modern
228	Deposit	0.01–0.05m deep	Deposit of copper slag and clinker, green and black in colour. Overlies deposit (227). Underlies re-deposited natural (224).	Modern
229	Structure	Unknown	Limecrete. Observed only partially. Buff in colour and fairly friable in texture. Contained frequent ash or coal inclusions throughout, as well as occasional patches of unslaked lime, white in colour.	Modern

Trench 3

Trench 3 was NE/SW aligned and was positioned 2.5m to the east of Trench 1. The trench was, furthermore, positioned 1.9m from the south-western perimeter of the Musgrave Engine House and Rolls Scheduled Monument (SMGm483). In total, the trench measured 14.7m in length x 2.4m in width. The height at the top of the trench was recorded at 7.04mOD at its south-western end and 7.19mOD at its north-eastern. The height at the base of the trench varied. Towards the south-western end of the trench, where concrete floor [302] was uncovered, the base height was recorded at 6.8mOD. Towards the centre of the trench, the base height was recorded at 6.15mOD. Finally, towards the north-eastern end of the trench, where annealing furnace [318] was uncovered, the base height was recorded at 6.5mOD. In total, the area covered by Trench 3 was 31.4m^2. The average depth of excavation was 0.45m.

Context	Type	Depth/Dimensions	Description	Period
301	Deposit	0.2–0.4m deep	Demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix.	Modern

302	Structure	0.24m deep	Concrete floor. Formed main floor of Hafod plate rolling mill.	Modern
303	Structure	0.18m diameter	Steel/cast iron water pipe. Heavily corroded on exterior. Ran in *c* NW/SE direction through centre of trench.	Modern
304	Structure	0.09m deep x >0.6m long	Remains of concrete floor/surface. Ran beyond eastern edge of trench.	Modern
305	Deposit/structure	>0.7m wide	Possible remains of culvert/flue. Composed of bricks. Probably constituted large section of rubble, rather than being an in-situ feature.	Modern
306	Structure	0.06m deep	Infill of concrete between concrete [304] and pip [303].	Modern
307	Structure	0.1m deep	Concrete lip on north-eastern edge of concrete [304]. The intersection between [304] and [307] indicated that the latter was poured on top of the former and was therefore a later addition.	Modern
308	Structure	>1.42m long x 0.6m in width	Brick wall. c E/W aligned. Composed of unfrogged refractory bricks, yellow and orange in colour, and bonded with a grey, ashy lime mortar with rare flecks of unslaked lime throughout.	Modern
309	Structure	0.34m wide x >1.85m long	Wall, formed of masonry. c E/W aligned.	Modern
310	Structure	0.01m thick	Pair of steel plates overlying wall [309]. Cut to fit precise shape of two visible pieces of masonry associated with wall [309].	Modern
311	Structure	>0.54m deep	Wall. Broadly E/W aligned. Composed of unfrogged red bricks in grey lime mortar. Abuts wall [309]. Forms part of [318].	Modern
312	Deposit	>0.54m deep	Deposit of pitch covering wall [311]. Likely associated with pipe [303].	Modern

313	Structure	0.47m^2 in plan	Small structure, square in form, that projected slightly beyond the uppermost course of [314]. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
314	Structure	1.7m long x 0.9m wide x 0.5m deep	Wall. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
315	Structure	0.3m wide x c 1.8m long	Apparent partition wall between [314] and [315]. Heavily root damaged. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
316	Structure	0.5m deep	Steps of northwest edge of [308]. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
317	Structure	>2.05 long x >1.6m wide	Brick surface. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
318	Structure	>4.7m x 1.8m in plan	Annealing furnace. Composed of features [311]–[317].	Modern
319	Deposit	0.4–0.7m deep	Demolition deposit below (301) comprising brick rubble and brick dust with some large pieces of masonry throughout.	Modern
320	Deposit	0.7m deep	Demolition deposit overlying (321) comprising large fragments of demolition material, mostly masonry, in a matrix of grey lime mortar and gravel.	Modern
321	Deposit	0.1m deep	Deposit of clinker and colliery waste underlying deposit (320).	Modern
322	Deposit	>0.25m deep	Re-deposited natural (mid-yellowy brown silty clay with rounded sandstone fragments). Overlies deposit (323).	Modern
323	Deposit	>0.2m deep	Deposit of brick rubble, brick dust and slag in a	Modern

			reddish gravelly clay matrix. Underlies (322). Possibly same as (325).	
324	Deposit	>0.5m deep	Deposit of clinker and colliery waste. Abuts northeast edge of concrete [302].	Modern
325	Deposit	>0.3m deep	Demolition deposit of brick dust and rubble. Abuts northeast edge of concrete [302]. Possibly same as (323).	Modern
326	Structure	0.5m deep	Steps of northwest edge of [314]. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
327	Structure	>2m long x 0.6m wide	Area of repair works within surface [317]. Composed of unfrogged red bricks in grey lime. Forms part of [318].	Modern
328	Structure	8m long x 5m wide	Possible quenching pool defined on its southwest and northeast by [302] and [311] respectively. Interpretation remains tentative.	Modern
329	Deposit	>0.5m deep	Colliery waste deposit, black in colour and highly friable. Below concrete [302].	Modern

Trench 4

Trench 4 was broadly aligned E/W and was rectangular in form, measuring 3.9m in length x 1.9m in width. In terms of position, the trench was located towards the base of the retaining wall separating the study from Morfa Road to the west. The trench was also positioned 2.6m south of Trench 1. The height at the top of the trench was recorded at 7mOD, while the height at the base of the trench was recoded at 6.6mOD at its deepest (western) end. At this level, the water table was encountered, meaning that significant ingress occurred across the entirety of the trench. As a result, excavations were limited to this depth. Both the excavation and recording of the trench was intermittent, as it necessitated the periodic removal of water via machine. In total, the area covered by Trench 4 was 6.96m^2. The average depth of excavation was 0.4m.

Context	Type	Depth/Dimensions	Description	Period
401	Deposit	0.4m deep	Demolition material, most notable masonry, brick, metal, and concrete in a	Modern

			dark brown silty clay matrix.	
402	Structure	>0.8m long x 0.2m wide	Wall composed of unfrogged red bricks bonded with black ashy lime mortar. Unknown function, initially thought to be part of manhole.	Modern
403	Structure	>0.4m long x >0.4m wide	Small stretch of wall partly observed seen in corner of Trench 4. Composed of unfrogged red bricks, mortar not observed. Unknown function, initially thought to be part of manhole.	Modern
404	Structure	>1.3m long 0.32m wide	Concrete drainage channel, concave in profile. Ran along western edge of Hafod plate rolling mill annex.	Modern

Trench 5

Trench 5 was irregular in form and covered a total area of 37.1m^2. In terms of its position, the trench was situated approximately 4.3m north of Trench 2 and 4.4m southeast of Trench 3. Furthermore, the northernmost (lateral) edge of Trench 6 was positioned in parallel alignment with the southernmost edge of Trench 5, with the two trenches eventually being joined up at this point for the purposes of obtaining a clearer view of the archaeological features uncovered within, which pertained to the interior of the Hafod plate rolling mill. The height at the top of the southern end of the trench was recorded at a 7.49mOD, while the height at its northern end was recorded at 7.3mOD. The height at the base of the trench was recorded at 7mOD at its deepest. The average depth of excavation was 0.4m.

Context	Type	Depth/Dimensions	Description	Period
501	Deposit	0.1–0.33m deep	Demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix.	Modern
502	Deposit	0.02–0.1m deep	Deposit of scree overlying concrete floor [503]. Highly fragmented, survived only in patches.	Modern
503	Structure	>8.9m x >4.2m in plan	Concrete floor of Hafod plate rolling mill. Varied thickness with multiple split levels observed throughout.	Modern
504	Structure	3m long x 0.8m wide	Moulded machine base uncovered in east edge of	Modern

			trench. Likely formed part of the plate flattening machine. Also, Likely the same as [504] in Trench 5.	
505	Structure	Unknown	Armoured electric cable recorded within machine base [504]. Ran in broadly NE/SW direction from within or beneath concrete [503].	Modern
506	Structure	0.66m x 0.42m in plan x 0.4m deep	Manhole composed of red frogged bricks topped with shuttered concrete to the same level as concrete surface [503]. Attached to *c* E/W running drainage channel.	Modern
507	Structure	0.13m long x 0.07m wide	Remains of vertically set RSJ, set into concrete floor [503]. Associated with RSJ [511]. Also related to machine base [504].	Modern
508	Structure	0.74m long x 0.41m wide x 0.39m deep	Manhole composed of red frogged bricks topped with shuttered concrete to the same level as concrete surface [503]. Broadly runs in NW/SE direction.	Modern
509	Structure	0.68m long x 0.4m wide	Manhole set within concrete floor [503]. Discovered in highly ruinous state.	Modern
510	Structure	0.13m wide x >2.25m long	Horizontally set steel rail uncovered towards northeast corner of trench. Probable mechanism for live rolling tables within Hafod late rolling mill. Set within concrete [503].	Modern
511	Structure	0.13m long x 0.08m wide	Remains of vertically set RSJ, set into concrete floor [503]. Associated with RSJ [510]. Also related to machine base [504].	Modern

Trench 6

Trench 6 was broadly E/W aligned and was positioned parallel to, and 2m north of, Trench 2. Initially, the trench was linear in form, measuring 13.8m in length x 1.9m in width. However, the trench was extended slightly northward and was joined up with Trench 5. This was accomplished for the purposes of obtaining a clearer view of the archaeological features

uncovered within both trenches, which pertained to the interior of the Hafod plate rolling mill. The height at the top of the western end of the trench was recorded at 7.23mOD, while the height at its eastern end was recorded at 7.36mOD. The height at the base of the trench varied. At its western end, the base height was recorded at around 6.5mOD at its deepest, while towards its eastern end, where the floor of the Morfa plate rolling mill was uncovered, the base height was recorded at 7mOD. The deepest point of the trench, represented by the interior of feature [617] towards its east end, was recorded 6.46mOD. In total, the area covered by Trench 6 was 27.63m^2. The average depth of excavation was 0.5m.

Context	Type	Depth/Dimensions	Description	Period
601	Deposit	0.1–0.3m deep	Demolition material, most notable masonry, brick, metal, and concrete in a dark brown silty clay matrix.	Modern
602	Deposit	0.03m deep	Organic horizon below (603). Represents historic turf layer formed after the demolition of the works.	Modern
603	Deposit	0.1m deep	Scree deposit, loosely bonded with cement. Highly fragmented and patchy.	Modern
604	Deposit	0.15m deep	Organic horizon Underlying (603). Historic topsoil.	Modern
605	Deposit	0.1–0.4m deep	Dark brown loam with brick fragments throughout. Underlies deposits (601) and (604).	Modern
606	Structure	0.6m^2 in plan x >0.3m deep	Concrete deposit. Probably represents one of the floor surfaces of the plate rolling mill annex. This concrete appeared as a slab penetrating the south-facing section, on the northern edge of the trench. It also ran beyond the limit of the trench to the east.	Modern
607	Structure	>0.2m x 0.4m in plan x >0.34m deep	Concrete deposit concentrated to the small area above wall [612] at the point at which the possible anchor plate was situated.	Modern

608	Cut	0.5m wide x 0.4m deep	Drainage channel. Cut directly through demolition deposit (605). In form, it had a concave base and relatively steep sides. Contains 2 fills – (609) and (610). Cut after the demolition of the works.	Modern
609	Deposit	0.8m deep	Primary fill of drain [608]. Composed of light greyish yellow sand,	Modern
610	Deposit	0.3m deep	Upper fill of drain [608]. Composed of gravel mixed with dark grey/black demolition material.	Modern
611	Deposit	>1.5m x 0.5m in plan	Re-deposited natural comprising mid-yellowy brown silty clay with frequent rounded sandstone inclusions. This deposit extended beyond the northernmost and southernmost limits of the trench.	Post-medieval/modern
612	Structure	0.9m below top of trench	Short stretch of sandstone masonry bonded with a buff or yellow coloured lime mortar with frequent flecks of unslaked lime throughout. Possibly ran in a c N/S direction.	Post-medieval
613	Structure	Unknown	Armoured electric cable. Ran in a broadly N/S direction beyond the northern limit of the trench. It is likely that this cable ran into the lower bay of machine base [504] in Trench 5. Underlies deposit (605).	Modern
614	Structure	>3.5m wide x 0.8m long 0.15m deep	Poured concrete. Originally comprised floor deposit associated with Hafod plate rolling	Modern

			mill (or annex). Destroyed during demolition of works.	
615	Structure	0.16m wide x >3.2m long	Linear stretch of concrete forming possible machine base (shears).	Modern
616	Structure	0.14m^2 in plan	Remains of vertically set RSJ set directly within concrete [614]. Associated with machine base [615].	Modern
617	Structure	>1.5m long x 0.6m wide x >0.48m deep	Feature associated with quenching bosh. Possibly a machine pit used for lower and raised copper in and out of a quenching bosh. Compositionally it comprised a simple gap in concrete surface [620], and was likely formed via the placement of shuttering, which demarcated its edges during the pouring of the concrete that constituted [620]. Incorporated into its southern end were a pair of notches, both of which extended 0.1m beyond the south-eastern and south-western corners of the bosh. These notches would have facilitated the vertical movement of some form of implement, allowing it to enter and exit the bosh. Filled with (618).	Modern
618	Deposit	>0.48m deep	Fill of feature [617]. Mid-reddish brown silty clay with frequent demolition material throughout, including brick and masonry fragments as well as sections of plastic	Modern

			sheeting. This fill was also seen to contain a bag of cement-based sealant, possibly grout, which had been cut open, meaning its contents formed a heavily compacted layer beginning 0.48m below the top of the bosh.	
619	Structure	>7.8m long x >2.1m wide x 0.2m deep	Additional concrete surface overlying [614].	Modern
620	Structure	See [503]	Additional concrete surface immediately north of concrete [614]. This surface was the same as [503], as uncovered within Trench 5 – a fact firmly established by the merging of Trenches 5 and 6. Only partially recorded within Trench 6, prior to its extension northward into Trench 5	Modern
621	Structure	>0.34m x 0.9m	Machine base on northern edge of Trench 6. Only partially observed. Likely the same as [504] in Trench 5.	Modern
622	Structure	0.26m^2	Possible machine base or manhole incorporated into concrete floor [614].	Modern

7.4 Appendix IV – YIM Uniflow Document

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Appendix – YIM Uniflow Document

THE UNIFLOW STEAM ENGINE OF MESSRS. YORKSHIRE IMPERIAL METALS, SWANSEA

This engine which powers the rolling mill, was manufactured by John Musgrave and Sons, Globe Ironworks, Bolton, in 1910 and is calculated to be of approximately 650 hp.

The uniflow design was thelast major development of the reciprocating steam engine andwas not perfected until 1906 (some sources say 1908) by Professor J. Stumpf of Charlottenburg. Its principle of operation; that of end admission of steam and central exhaust, to avoid constant reversal of fluid and consequent loss of efficiency due to repeated heating and cooling of the cylinder, had occurred to Perkins in the U.S.A. and to L.J. Todd in England in 1886, but no successful machines were made. Thus all such engines manufactured in Britain were made to Stumpf patents. The first British licencees were John Musgrave and Sons, in 1910.

Uniflow engines were simple and efficient and were extensively used in many industries, however very few seem to have survived. A survey conducted by the Centre for the Study of the History of Technology at Bath University in 1976 lists only six other uniflow engines :-

Littleton Pumping Station, Metropolitan Water Board.
two identical 750 hp engines by Worthington-Simpson, 1924 (disused)

W.H. & J. Barber, Holmfirth, Yorkshire.
one 520 hp engine by Clayton & Goodfellows, 1922

Dobroyd Ltd., Holmfirth, Yorkshire.
one 400 hp engine by Woodhouse & Mitchell, 1920 (disused)
one 500 hp engine by Pollit & Wigzell, 1924 (disused)

Birmingham Museum of Science & Technology.
one small Galloway engine of 1924.

The last mentioned is noted in the above survey (THe Industrial Archaeology of the Stationary Steam Engine) to be the only example so far preserved. It will also be seen that the Swansea example has the additional merit of being by far the oldest survivor, and one of the earliest of its class in the country.

The main features of the Swansea Uniflow engine, and its relation to some of the ancillary equipment are shown in the attached drawing. It has had no major attention since its rebore by Messrs. Buckley & Taylor of Oldham in 1937, but appears to be in good order.

Theattached calculations give some idea of the current demand for steam and cooling water while theengine is driving the mill. Obviously, the maximum power which can be developed , will never be required in preservation. What has not been determined is, what fraction of the available power is used to drive themill, and what fraction turns the engine. It is probably safe to assume that only one tenth is used to propel the engine, and thus figures for steam consumption etc. could be reduced proportionally. Perhaps the present owners would allow us to try running it with no load and at a very much reduced pressure to confirm this?

Auxilliary Plant

a) Condenser

Theengine is a condensing engine and derives some of its power from the vacuum created when the exhaust steam is condended in an external chamber, the condenser, which is located beneath the engineroom floor and is cylindrical in shape, having internal dimensions of 80 in length and 34 in diameter.

The existing condenser is of the jet type. That is a spray of relatively cold water is injected into the exhaust steam to cause it to condense and the output is relatively hot water equal in mass to the sum of thesteam and injected water.

Originally this operated as shown in diagram (A), withwater being drawn from the Swansea Canal and output passing to the Tawe. Later this was altered to the system shownin diagram (B), which is the present system.

diagram (A)

advantages:-

1) no pumping costs
2) much simpler than existing system therefore reduced maintenance costs.
3) no unsightly plant
4) because of a continuous supply of coolant at ambient temperature, the condender can be kept cooler, which in turn, decreases the back pressure on theengine and hence leads to increased efficiency.

disadvantages:-

1) lubricating oil from theengine may be carried over in the condensate, and may require treatment at point x before discharge.
2) there would be a conciderable throughput of cooling water.
3) The temperature of the water leaving the condenser may not be acceptable to the Water Authority.

The last two points are inter-related, i.e. increasing the flow of cooling water would reduce the final temperature at the expense of using more, and both affect 4) above.

diagram (B)

This system was adopted by the company to reduce their consumption of fresh water. It forms a loop witha continuous cycle of events. Condensed steam and cooling water flow to the hot well (a). The mixture is then pumped by two 13·5 hp pumps to the top of a natural-draught cooling tower (c). From here it flows to the 'cold well' (b), which in turn supplies the jet of condensing water. The loop has a considerable input of additional water in theform of condensed steam, but a simmilar mass is lost in the cooling tower. As the cooling tower is affected by atmospheric conditions, water can be added or withdrawn from it as shown, to maintain a constant level.

diagram (C)

This isa modification of the original system at (A) and uses a modern surface condenser so that cooling water and condensate do not mix.

advantages:-

1) Theunnecessary complications of (B) can be dispensed with.
2) The new condenser can be mounted under the enginerwom floor in place of the existing one and the 'Cold well' would then become the 'hot well' (b).
3) The condensate in (b) can be used as boiler feed water which would save fuel as its elevated temperature reduces energy input to the system here.
4) More easily balanced than the system shown in (B) as the mass of condensate must equal the mass of steam consumed. Thesystem only requires topping up because of evapouration losses.

disadvantages:-

1) Whatever the chosen operating conditions, an increased throughput of cooling water can be expected over systems using a jet condenser.
2) Some cost would be involved in converting the engine.
3) Some modern package boilers require special purity water and thus the water from the 'hot well' may not be acceptable.

diagram (D)

Here the exhaust is vented to atmosphere, dispensing with the condenser entirely.

The engine wouldwork this way, but there would be an increased fuel bill for steam raising.

(E)

This is a modification of (A) using tap water. As explained, the throughput of water depends on the desired outlet temperature.

advantage:-

1) Setting-up cost minimal

disadvantage:-

1) Running cost may be higher than (C) as fresh boiler feed water has to be heated from cold.

Thus (C) or (E) would seem to be the most desirable for a preserved engine.

b) Boiler

The existing boilers are of three forms. There are three Lancashire boilers, none ofwhich are in working order. Two retain there original grates for coal firing, and the third has been converted to burn heavy oil. A modern pachage boiler has recently been supplied by Robey of Lincoln Ltd. Thisalso burns heavy oil and has a maximum continuous output of 18,000 lb / hour at 180 lbf / in^2 gauge. All the boilers are about 300 ft from the engine. This is inconvenient and wasteful as the steam is wet on reaching the engine.

~~be required~~, and even if additional steam engines were operated, using any of the existing boilers would not be economical especially as they would have to be resited nearer to the engine. In the case of a Lancashire boiler, this would be very costly indeed.

A small package boiler situated close to the engine house would seem to be the answer.

STEAM CONSUMPTION OF ENGINE

Thesteam consumption of a reciprocating steam engine, particularly one of the uniflow type, is extremely difficult to measure directly.

Themethod employed at Yorkshire Imperial Metals was to assess the hourly consumption of other processes usingsteam and to subtract these from the known output of the boiler. Their estimate was thus 8,000 lb / hour, and this is likely to be a high estimate because of considerable losses due to leakage.

An alternative indirect method is shown below:-
From existing drawings, the cylinder bore was found to be $28\frac{1}{8}$ in.
piston rod diameter $6\frac{1}{4}$ in.
and length of stroke to be 3 ft 3 in.
Hence the volume of the cylinder was found to be 14·3 ft^3.
Now there is no record of the point at which the steam is cut off by the inlet drop valves and this could not be measured when the engine was running, so a typical figure of 0·074 stroke was taken from an indicator card in Heat Engines by Prof. Low.

The engine was timed to perform 120 rev/min. and is double-acting

Thus the volume of steam taken per hour is :-

$$14{\cdot}3 \times 0{\cdot}074 \times 120 \times 2 \times 60 = 15{,}200 \text{ ft}^3$$

The pressure gauge read 172 lbf/ in^2, gauge
and from tables, this was found to have a specific volume of 2·466 ft^3 / lb.
which gives an hourly steam consumption of 6,160 lb

This is likely to be a low estimateas no account of the dryness fraction of the steam on entry or of clearance volume has been taken.

However, using the same method, if the engine was de-rated to run at 80 rev/min on dry saturated steam at 50 lbf/in^2, the steam consumption would be approx.

1,700 lb/hour

The Theoretical Horsepower of the Engine under the Observed Conditions was:-

$$\text{mean effective pressure} = \frac{\text{inlet press.}}{r} \cdot (1 + \ln r) - \text{back pressure}$$

r is the expansion ratio and is 13·5, the reciprocal of o:074
inlet pressure is 190 lbf/in^2 abs.
vacuum in the condenser was measured as 25·5 in Mercury ≡ 2·5 lbf/in^2 abs.
Hence mean effective pressure 48 lbf/in^2

$$\text{Now hp} = \frac{\text{mean effective press. x piston area x length of stroke x no. of strokes}}{33{,}000}$$

$$= \frac{48 \times 590 \times 3.25 \times 240}{33{,}000} = 670$$

FLOW OFWATER THROUGH CONDENSERS

Prof. Low, in Heat Engines , gives an approximate formula for the specific mass of water required to flow through a condenser under any given conditions.

It is :- $W = \frac{xH + (t - t_1)}{(t_3 - t_2)}$

where W = mass of water/lb of steam
x = dryness fraction of steam (taken as unity for an approx. calculation)
H = specific enthalpy of inlet steam
t = temp. of onlet steam = 135 F
t_1 = final temp. of condensed steam = 95 F say
t_2 = initial temp of condensing water = 60 F say
t_3 = final temp. of condensing water = t_1 here because the two mix

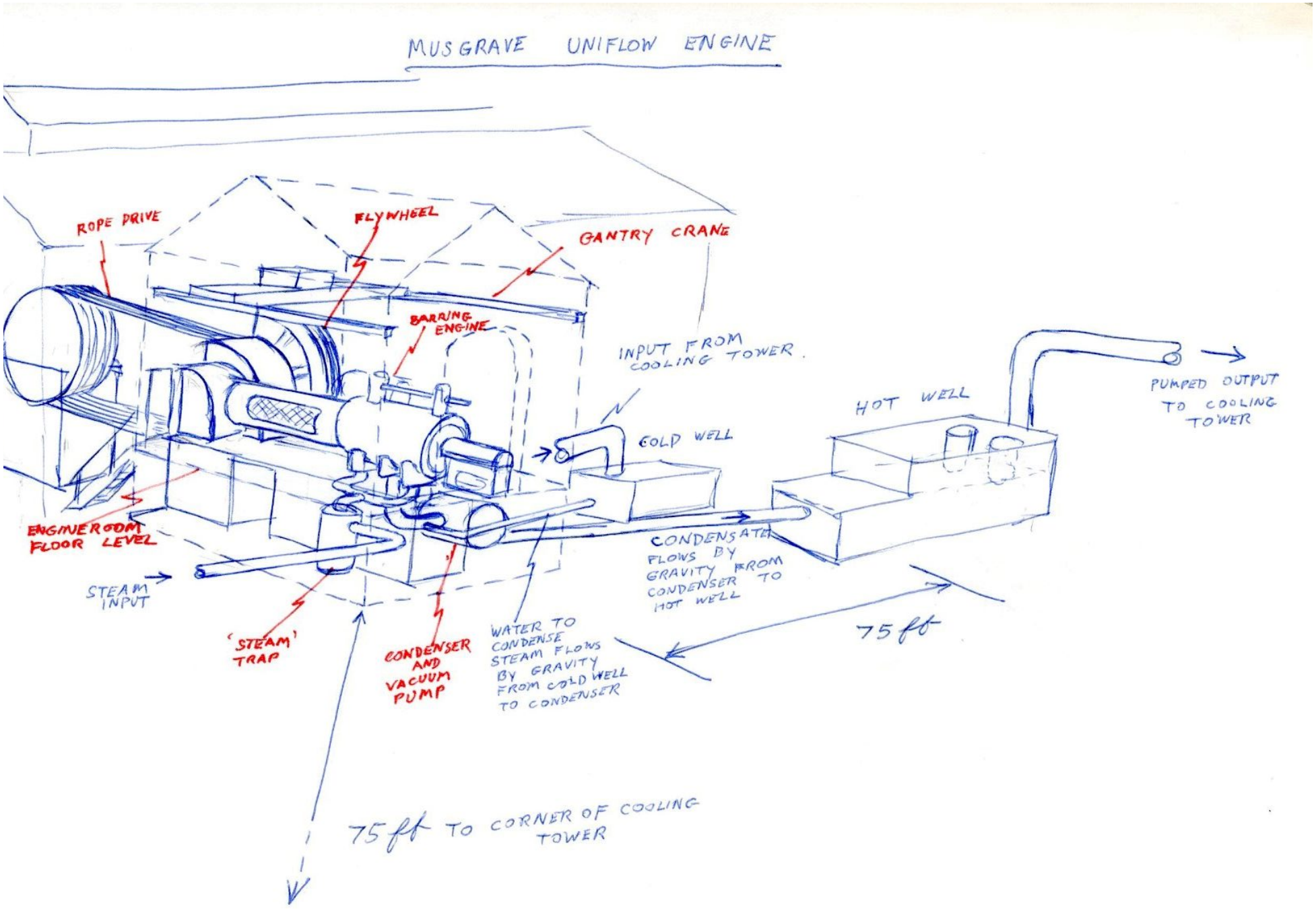
H = 1017 Btu/lb from tables

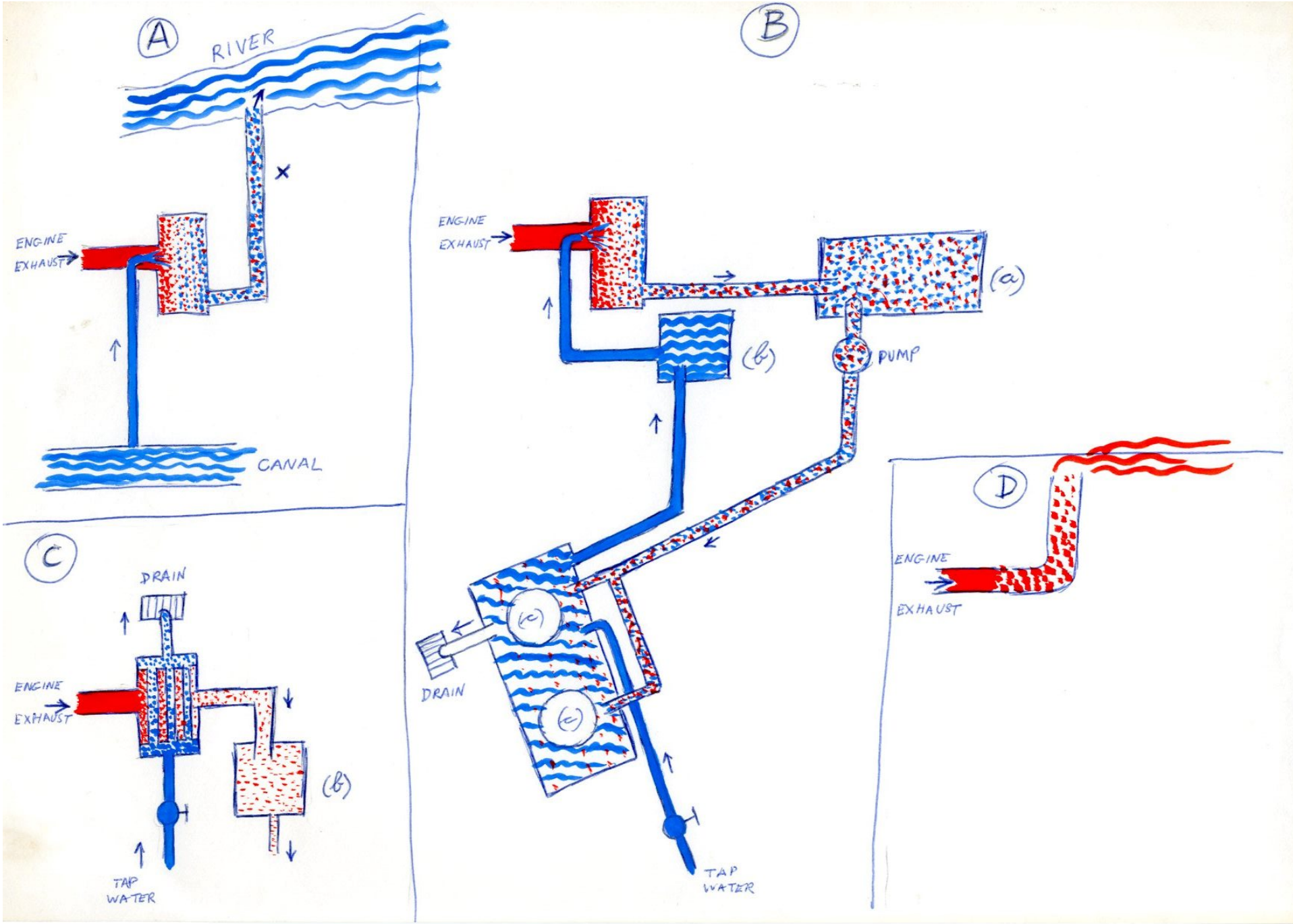
Hence w = 31 lb / lb

or approximately 3 gallons of water must flow through the condenser forevery pound of steam used

Thus thepresent flow of water through the cooling tower is mass of steam x 3 = 21,000 gal. + volume of condensed steam (700 gal.)
= approximately 22,000 gallons per hour

MUSGRAVE UNIFLOW ENGINE




A
RIVER
ENGINE
EXHAUST
CANAL
B
ENGINE
EXHAUST
(a)
(b)
PUMP
(c)
(c)
DRAIN
TAP
WATER
C
DRAIN
ENGINE
EXHAUST
(b)
TAP
WATER
D
ENGINE
EXHAUST

7.5 Appendix V – Social Media Posts for the Copperworks Discovery Project

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PROSIECT DARGANFOD Y GWEITHIAU COPR 2021

Mae Gwirfoddolwyr Eisiau

Rydym yn gyffroes i gyhoeddi prosiect archeoleg cymunedol newydd yn y Gweithiau Copr byd-enwog Hafod-Morfa yn Abertawe, unwaith y gweithiau copr mwyaf yn y byd

Rydym yn chwilio am wirfoddolwyr i gymryd rhan yn y prosiect 5 diwrnod, a fydd yn digwydd rhwng

dydd Llun 8fed – dydd Gwener 12fed Tachwedd 2021.

Nid oes angen profiad,
jest dewch draw a chael hwyl cloddio darn of hanes Abertawe!

Byddwn yn cynnal digwyddiad lansio rhithwir ar

dydd Mawrth 26ain Hydref am 7.30pm

er mwyn cyflawni'r prosiect, cloddiadau archeolegol diweddar, hanes ehangach y gweithiau copr, ac i ateb unrhyw gwestiynau sydd gennych. Bydd recordiad o'r digwyddiad ar gael i'r rhai na allant ddod.

I gael mynediad i'r digwyddiad neu i gofrestru'ch diddordeb, cysylltwch ag Abbi Wootten-Brooks ar **abbi@bmarchaeology.com**

@BMArchaeology

@blackmountainsarchaeology

Black Mountains Archaeology Ltd

Gwnaed yn bosibl gan | Made possible with
Cronfa Treftadaeth Heritage Fund

City and County of Swansea · Dinas a Sir Abertawe ·

Prifysgol Abertawe Swansea University

- BLACK MOUNTAINS ARCHAEOLOGY -
- ARCHAEOLEG MYNYDD DU -

Welsh flyer advertising the Copperworks Discovery Project

English flyer advertising the Copperworks Discovery Project

7.6 Appendix VI – School Visit Activity Sheets for the Copperworks Discovery Project

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- BLACK MOUNTAINS ARCHAEOLOGY -
- ARCHAEOLEG MYNYDD DU -

Cronfa Treftadaeth Heritage Fund

Guess the Find!

Can you guess what each of these items were used for at the copperworks?

Prifysgol Abertawe Swansea University

Cyngor Abertawe Swansea Council

_____

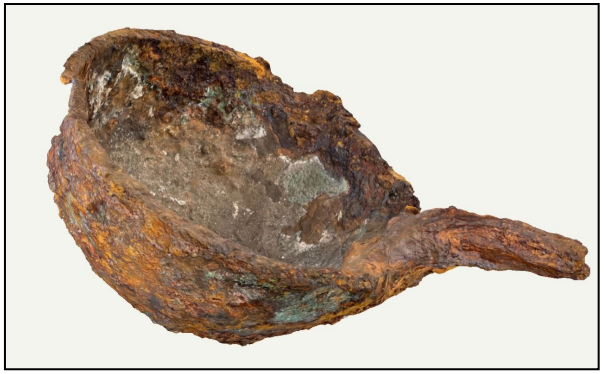
_____

_____

_____

_____

_____



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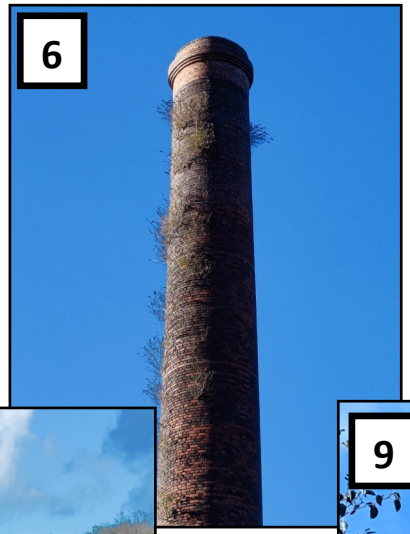
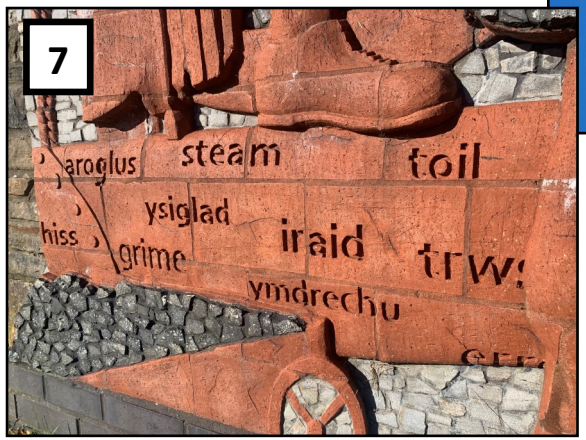
Copperworks Treasure Hunt

Look high, look low… can you match these photos to a place at the copperworks?





7.7 Appendix VII – List of Volunteers

Aashina Anand	Adele Vye
Brian Lewis	Calum Sweeney
Caroline Morris	Cathryn Richards
Chris Jones-Jenkins	Donna Arnold
Gary Grove	Guihem Bibault
Helen Nicholas	Jake Goggin
James Hope	Jamie Hyett
Janet Bailey	Jeff Jones
Judith Thomas	Julie O'Connor
Kerim Rassim	Kim Couch
Mike Prankerd	Natalie Williams
Olivia Casey	Peter Richards
Phillipa Farrell	Rhian Evans
Rose Harrison	Sandy Johns
Sarah Thompson	Selena Hardie
Shoaib Mohammed	Shubhankar Anwekar
Sian Davies	Stuart Hale
Sue Ware	Tom Henderson
Arthur Green	

- BLACK MOUNTAINS ARCHAEOLOGY -
- ARCHAEOLEG MYNYDD DU -

Yn rhan o'n hawydd i wella ansawdd ein gwasanaeth, rydym yn croesawu unrhyw adborth y gallwch ei ddarparu.

As part of our desire to improve our quality of service we welcome any feedback you are able to provide.

Archaeoleg Mynydd Du Cyf/Black Mountains Archaeology Ltd
Swyddfa Gofrestredig/Registered Office: Unit 23 The Innovation Centre Festival Drive, Victoria Business Park, Ebbw Vale, Wales, NP23 8XA

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Gwefan/Web: https://blackmountainsarchaeology.com/
Cymdeithasol/Social: https://twitter.com/bmarchaeology?lang=en-gb