Surface Water Management to Reduce Pollution at Dylife, Mid Wales

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Abstract

The abandoned Dylife metal mine presents many legacy issues and environmental constraints requiring consideration when developing remedial solutions. Extensive monitoring and conceptualisation of pollution pathways has allowed the development of a phased approach dealing with identified pollution sources. The ambition is to manage surface water to reduce the need of installing a mine water treatment system, which is subject to post-intervention monitoring and validation. Surface water management is presented as an effective tool at many legacy metal mines with lodes typically worked to surface and intimately connected with watercourses that continue to be polluted many years after mining has ceased.

Keywords: Surface water management, erosion, run-off, intervention, drainage

Introduction

The former Dylife Pb and Cu mine is situated 16 km northwest of Llanidloes, Powys within the upper Afon Twymyn catchment, a tributary of the Afon Dyfi which flows into Cardigan Bay at Aberdyfi. Pb mining began in Romano-British times and the Roman fortlet Pen y Crocbren sits atop the mountain to the south of the now abandoned underground mine site. Mineral exploitation is recorded from 1640 with almost 37,000, 1,500, and 400 tonnes of Pb, Cu and Zn ores respectively produced between 1845 and 1901 (Bick 1985). A later attempt to recover metal by reprocessing old spoil tips in the 1920s resulted in extensive riverside spoil deposits to the north, separated from the rest of the site by a modern road embankment that crosses much of the former mill and mineral processing area. The layout and extent of the mine is shown on Ordnance Survey maps from the late 19th Century (fig. 1).

No remediation or restoration was undertaken upon abandonment and the site continues to pollute the entire length of the Twymyn contributing significant metal loading to Dyfi, which is also polluted by other abandoned mines to a lesser degree. The mine pollution is confirmed as a principal reason for the Twymyn waterbody not achieving Good status and the site has been identified as a target for improvement under the joint Metal (Non-Coal) Mine Programme (MMP), a partnership between Natural Resources Wales (NRW) and the Coal Authority.

The mine sits immediately above the impressive Ffrwd Fawr Waterfall and the northerly draining Twymyn Gorge, all within the Dyfi Biosphere area. The large deposits of riverside spoil known as the Great Tip and Hirnant Tip are designated as a geological Site of Special Scientific Interest (Dylife Mine SSSI). The mine site to the south and west of the road embankment is not formally designated but contains further spoil deposits and other important mine heritage features including parts of the former dressing floor, the 19.2 m diameter Red Wheel pit and in-situ pumping rods in the Llechwedd Ddu Engine Shaft. Ecological surveys of the site have confirmed the presence of large established Calaminarian Grassland species and habitat (Simkin 2014) including the nationally rare Lead-moss Ditrichum plumbicola (Pryce 2020).

The assessments (PB 2005, URS 2012, AECOM 2016) and feasibility study (Coal Authority 2020) have confirmed a number of active pollutant linkages and identified potential intervention targets for each linkage. Local infiltration and surface water / groundwater interaction is controlled by historical mining activity (surface and underground). The local bedrock comprises the turbidite sequences of the Silurian Rhayader Mudstones Formation that would have very limited natural groundwater flows, restricted to post-lithification fractures and mineralisation zones. Due to the complexity of underground workings, surface spoil deposits and surface water run-off a staged approach to design and implementation of surface water management measures is recommended. This will enable the effectiveness of each stage to be assessed before starting the next. Measures to control infiltration, reduce erosion and minimise contaminated surface run-off. Once these measures are in place, the need for treatment of remaining mine water discharges can be reassessed /confirmed.

Limiting Surface Water Inflows

The site sits at the confluence of Nant Dropyns and the Afon Twymyn, although the original confluence location is now buried beneath a newer road embankment, road junction and informal car park. Upstream of the confluence, both watercourses are ephemeral, losing their flow entirely in some reaches during drier conditions. Mine workings on the southwest – northeast trending Esgairgaled Lode are recorded beneath both watercourses, with numerous connections with the surface suspected but not visible due to the channel bed infill. The Llechwedd Ddu Lode trends almost along the Twymyn channel and was accessed via the Llechwedd Ddu Engine Shaft, that remains open and visible on the slope above the right-hand bank of the river. There is a junction between the two lodes upstream and the Esgairgaled workings are connected to the Llechwedd Ddu workings via a crosscut adit, referred to as Level Goch (Bick 1985). Further connection to the Esgairgaled workings was made by driving another cross-cut north 73 m, although this was then abandoned due to

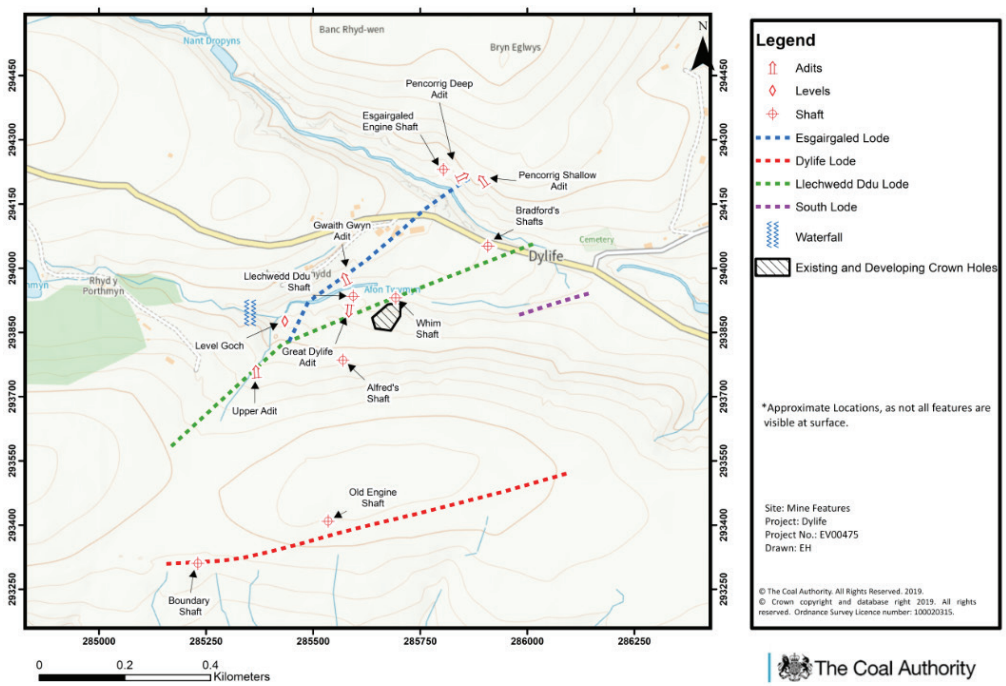

Figure 1 *Schematic plan identifying the lodes and mine entries at Dylife and Dyfngwm mines.*

excessive water ingress. Improved pumping capacity was required to permit expansion and exploitation of the rich Pb ore to the north of the river (James 2014).

The Llechwedd Ddu workings drain via an adit from the Whim Shaft (fig. 1) further east and downstream, i.e. at an elevation lower than the losing channel reach. This Llechwedd Ddu adit portal is now buried and discharges are suspected to be constricted, especially under high flow conditions with the Whim Shaft pool observed overtopping on occasion.

Water is also observed to re-emerge from the left-hand bank of the Twymyn immediately downstream of the rock tunnel under the modern road embankment, suspected to be the result of underground flow along the original Nant Dropyns channel to the former confluence location (Margary 1992). The latest conceptual site model infers substantial infiltration of river and stream flows into underground workings, with the constricted outflow leading to mine water levels rising and falling on a continual basis with the release of metal contaminated water to the downstream Afon Twymyn (fig. 2). Contamination is also introduced through the underground flows along the original Dropyns channel alignment now backfilled with spoil and overlain by an unsurfaced car park area, which represents the majority of Nant Dropyns flow in most normal weather conditions. In all cases, it is assumed that infiltration and flow through unmined bedrock is negligible. These water pollution pathways are exacerbated by the flashy nature of the small upland catchments that enhances the flushing effects of rising and falling water levels in mine workings and metalliferous made ground deposits. Surface water flow gauging and monitoring continues to further define losses to workings and help inform the design of proposed engineering interventions.

Installation of impermeable lining to the channel bed and banks has been identified as the most feasible option for preventing inflows of uncontaminated surface water into underground workings and metalliferous made ground deposits. Flows also need to be conveyed through and under the modern road

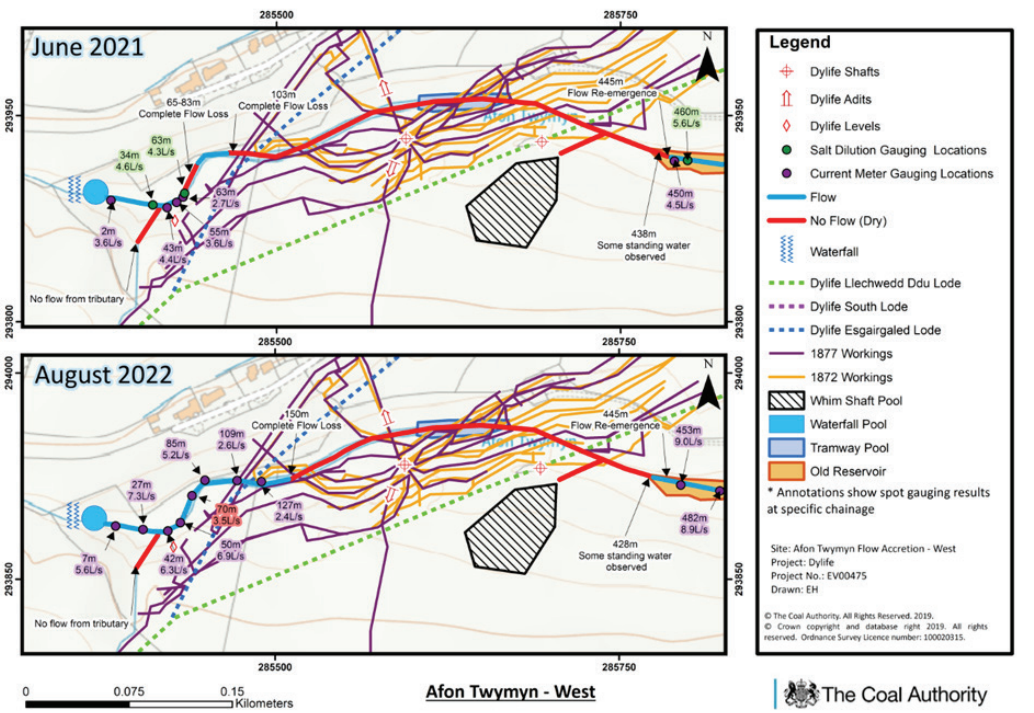

Figure 2 *Afon Twymyn flow gauging results revealing the scale and location of flow losses.*

embankment / car park area, as alternatives to crossing the remaining exposed dressing floor area thus entering the Afon Twymyn upstream of a constraining rock cut tunnel. Ongoing flow monitoring is critical to sizing the new culvert and lined channel sections. It is intended that on completion, the mine water levels in the flooded workings beneath the site will permanently revert to the base level of the buried discharge at the Llechwedd Ddu adit and be much reduced in volume. This will need to be confirmed and validated by post installation monitoring.

Preventing Erosion and Contaminated Run-off

Extensive monitoring, including source apportionment using salt dilution gauging and synoptic sampling has identified the remaining exposed dressing floor area and riverside spoil tips as major contributing sources of downstream metal pollution. The Twymyn channel is observed to directly erode spoil deposits and receive run-off from steep, gullied largely unvegetated slopes as the river traverses the main mine site and particularly as it runs directly along the toe of the Hirnant Tip within the eastern part of the designated Dylife Mine SSSI area (plates 1–3).

The Nant Dropyns has previously been diverted under the road from north to south and across the exposed former dressing floor. Although the channel is dry in low flow conditions, storm events can quickly result in very high flows through the channel, with severe erosion of fine grained ore processing spoil deposits. Much of the channel now is on bedrock downstream of the road culvert concrete / rip rap channel. Diversion of the Dropyns into the Twymyn upstream of an original rock cut mining tunnel results in backing up of the combined flows during severe storm / sustained heavy precipitation events. The frequency of these events has not been determined, but is likely increasing due to climate change, leading to further erosion of the bankside spoil deposits. The absence of defined drainage from the road embankment and adjacent land also leads to increased surface run-off, gullying the remaining dressing floor deposits and loss of mine heritage artefacts buried within it.

Due to the visible severity of the erosion and damage to vulnerable mine heritage features such as the bored wooden drainage pipes strapped with metal, early intervention measures were introduced. These used pre-filled 'rock roll' plastic mesh protection placed in front of the current eroded channel banks across the dressing floor and along the left-hand bank of the Twymyn that is subject to inundation and erosion during flooding (plates 4–5).

Additional erosion protection and drainage will be required to protect the main Hirnant Tip toe and other exposed spoil slopes directly adjacent to the Afon Twymyn. The upstream channel lining work is anticipated to also mitigate the erosion and run-off impacts in those sections. The erosion protection for the Hirnant Tip toe will need to be combined with interception drainage, to prevent hillside run-off infiltrating into the up-gradient spoil deposit and with surface drainage to prevent gullying of the exposed fine grained reprocessed spoil. This will involve reprofiling of the tip to provide separation from the bedrock river channel that can't be moved and to produce a long term stable landform with minimal ongoing maintenance or protection requirements. Alternative options included extensive

Figure 3, *4 & 5 Afon Twymyn looking downstream eroding Hirnant Tip toe.*

capping or off-site disposal of spoil were discounted at feasibility stage, although it is noted from a review of the Dylife Mine SSSI citation that the mineralogical interest of the site lies exclusively in the Great Tip deposit, which does not require extensive treatment at this stage.

The feasibility study (Coal Authority 2020) noted that if the proposed engineering interventions were insufficiently effective due to ongoing leachate seepages from the Dylife Mine SSSI deposits, there is an option to install passive treatment media within the toe drainage channels, to be designed based on future monitoring results. It is acknowledged that this would in turn require substantial ongoing maintenance to clear clogging and refresh absorbent media. Additionally, further engineering would be required to prevent river or clean surface runoff ingress into the toe drains as opposed to using simple French drains presently proposed.

Working with Environmental and Heritage Constraints

Abandoned metal mine sites are typically in remote, otherwise undeveloped areas and often allow the development of sensitive and unusual Calaminarian habitats that host a diverse mosaic of sometimes rare flora and fauna. This, along with associated formal designation of the habitat, geology or mine heritage features, usually prevents wholesale removal or encapsulation of identified pollution sources. The original Dylife mine has been obscured and degraded by subsequent mineral exploitation, such as the spoil reprocessing by Hirnant Minerals plus the lead works by the modern road embankment and car park. The remaining exposed mining features and diverse habitat merit ongoing preservation and protection.

The creation of sterile artificial channels and long culverts are counter to current 'green engineering' good practice and mitigation. They are however essential parts of pollution prevention interventions and can be designed more sympathetically and innovatively from the outset. They can incorporate sinuosity or thalwegs and steps to retain gravel substrate over the impermeable lining. New culvert sections can be provided with a mammal transit shelf to allow for unrestricted movement of animals along the riverbank under most flow conditions.

Surface water run-off from the site and surrounding areas needs improved management to attenuate surface flows and encourage conveyance around or through contaminated areas thereby restricting direct infiltration. Provision of effective drainage and landforms to more extensive areas of exposed spoil such as Hirnant Tips will also help reduce direct infiltration.

Spoil deposits sufficiently remote from active watercourses and not representing

***Figure 6** & 7 Erosion Protection Intervention in the Nant Dropyns Channel across the Former Dressing Floor, working in extreme wet conditions.*

notable pollution sources with direct run-off connection will remain in-situ undisturbed by future engineering works. Accordingly, sensitive and valuable habitats created by mining operations can be preserved without substantial reduction of essential pollution prevention interventions.

Conclusions

Dylife is a typical example of how historical metal mining activities continue to cause surface water pollution across the Western Wales River Basin District, despite having no visible discharge of mine water into the main river. Long standing problems centre on the absence of effective surface water management on and around this extensive site bisected by two watercourses and now with road infrastructure crossing the site. Surface water courses and run-off flowing into the underground workings and through surface spoil deposits lead to metal leaching and direct erosion of metal rich materials, resulting in substantial dissolved and solid phase pollution of the downstream Afon Twymyn and Dyfi waterbodies.

The superimposition of multiple pollution pathways within short river reaches means that quantification of individual pollution source contributions is very difficult. A phased approach to intervention is therefore necessary, so that the effectiveness of each phase can be evaluated and taken into consideration before the next is suitably refined and implemented.

Pollution prevention through the managed conveyance of clean water, reducing infiltration to mine workings and metal rich spoil deposits is central to the management of most abandoned mine sites. It is also important that long term stable landforms created as part of remedial interventions are sympathetic to the rich heritage and diverse habitats typically present on metal mine sites such as Dylife.

Acknowledgements

This study is funded by the joint Metal (Non-Coal) Mine Programme of NRW and The Coal Authority sponsored by Welsh Government. We extend our thanks to Dr Nina Menichino, Team Leader, Evidence Portfolio, Programmes and Processes at NRW for supporting this paper.

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