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Notes on a site visit to the abandoned Abbey Consols Mine, Mid-Wales

Groundwater Science Programme

Open Report OR/12/047

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GROUNDWATER SCIENCE PROGRAMME

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Front cover

View of Abbey Consols mine spoils.

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Foreword

The British Geological Survey (BGS) was commissioned in March 2012 by the Environment Agency-Wales (EA) to undertake a walkover survey to ascertain what additional information and data are required to develop a robust conceptual site model (CSM) of the Abbey Consols Mine, Ceredigion, Wales. This report is the published product of this study.

Acknowledgements

In addition to the collection of data, many individuals have freely given their advice, and provided the local knowledge so important in developing conceptual site models. In particular the authors would like to thank Dr Richard Shaw (British Geological Survey, Keyworth).

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Summary

The report describes the findings of a site visit and brief literature review in the context of the geology, hydrogeology and hydrology of the abandoned Abbey Consols metal mine in mid-Wales. Data presented in an ExCAL report provided by the Environment Agency have been reviewed, in particular with respect to the composition and chemistry of the spoil heaps. Consideration has been given to the conceptual site model and its associated uncertainties, which have been used to assess current proposals regarding remediation of the site.

1 Introduction

The British Geological Survey (BGS) was commissioned in March 2012 by the Environment Agency-Wales (EA) to undertake a walkover survey to ascertain what additional information and data are required to develop a robust conceptual site model (CSM) of the Abbey Consols Mine, Ceredigion, Wales. Particular attention has been given to the assessment of the significance of surface water runoff and groundwater pathways to the receiving Afon Teifi from the abandoned mine site, which is critical to determining the feasibility of any remediation scheme. The site visit was carried out on the 29th March 2012 by: BGS staff Vanessa Banks and Barbara Palumbo-Roe, accompanied by Tim Colman (ex-BGS); EA staff Paul Edwards, Helen McGann, Peter Stanley, and Atkins staff Richard Colin.

This report also refers to a previous report "Abbey Consols, Grogwynion and Castell Metal Mine study" undertaken in 1999 by ExCAL Limited under the management of Ceredigion County Council and funded by the EA.

The report describes the geology, hydrogeology and hydrology of the site, reviews data with respect to the composition and chemistry of the spoil heaps and describes some additional sampling, before considering the CSM and its uncertainties in terms of the source-pathway-receptor paradigm. In addition, some consideration is given to the viability of current proposals regarding remediation of the site.

2 Location

The mine site is located at NGR 274280 266105 (Figure 1). It was formerly known as Bronberllan, after the name of the adjoining farm (Jones, 1922).

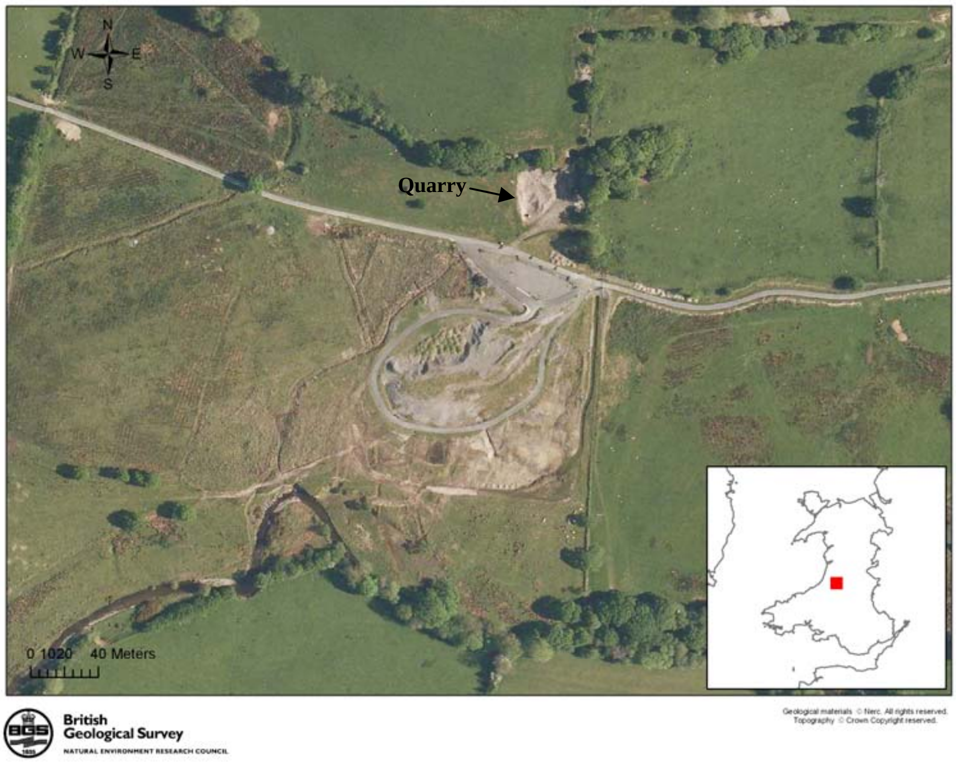

Figure 1 Location of Abbey Consols Mine (Aerial photography © Getmapping Licence No. UKP2006/01).

The Plan of Florida (Abbey Consols) mine from Coal Authority plans in 1905 shows the presence of an Adit Level with an adit entrance to the west and intersected by the main adit driven 70 fms (about 128 m) from the south starting at an elevation of 210 m (Jones, 1922). The section of the mine shows the Adit Level and also the lower levels to the 50 fm (about 90 m) Level. The shaft (although shown vertically on the section) will have been inclined at 55° to the south – parallel to the dip of the lode. The shaft intersects the adit at 45 m depth (downdip). It is understood (Paul Edwards, personal communication) that the mine adit may be situated near to the floor of the quarry. However, it has still to be located and consideration will need to be given to its condition, i.e. with respect to stability.

The mineralisation in the lode will have been composed of quartz, host rock breccia fragments and the economic minerals galena (PbS) and sphalerite (ZnS) in varying proportions. Most of the lode will have been barren host rock and quartz. Economic mineralisation occurred as narrow west-plunging oreshoots (Jones, 1922). The sphalerite probably contained around 0.2% cadmium and varying amounts of iron.

Ore would have been hand picked during the early stages of the operation of the mine. Later working would have used crushing and roller milling equipment to produce much finer material for various stages of washing (jigging) to separate and recover the ore materials (KP 17026: Old mine inventory of plant).

A photograph of the last known working of the mine, possibly taken around 1910, illustrates a series of tips and mine buildings (WMS, 2009).

Bedrock was exposed in the quarry immediately to the north of the site (Figure 1) and could be seen to be bedded and jointed (Figure 2). Scour marks on the quarry face are suspected to be wire hose marks made during the removal of plant from the floor of the quarry.

Figure 2 Bedrock exposed in the quarry to the north of the mine site

3 Geology

The site is underlain by a solid geology comprising the Silurian Devil's Bridge Formation (thinly interbedded turbidite sandstone and mudstone; DBF-MDSA, Figure 3), which overlies the Silurian Rhayader Mudstones (pale grey to green turbidite mudstones; RHS-MDST, Figure 3) that underlie the area immediately to the east of the site, reflecting the westerly dip of the strata. These sediments were laid down between 450 and 420 Ma. Subsequently they were subject to folding and uplift during the Caledonian Orogeny (Davies et al., 1997). They are dominated by illite and chlorite (Shand et al., 2005). Mineralization is focused on an east north-east to west south-west trending fault, which dips 55° to the south (Jones, 1922). The Abbey Consols mine lies within the Central Wales Mining Field (Jones, 1922) which has been worked intermittently since Bronze Age times. The main periods of working in the area was between 1850 and 1870 and the recorded working at Abbey Consols was between 1848 and 1909 (Jones, 1922). Some Central Wales mine tips were reworked for lead in the 1950s and 60s, but it is not thought that this occurred at Abbey Consols (George Hall, personal communication April 2012).

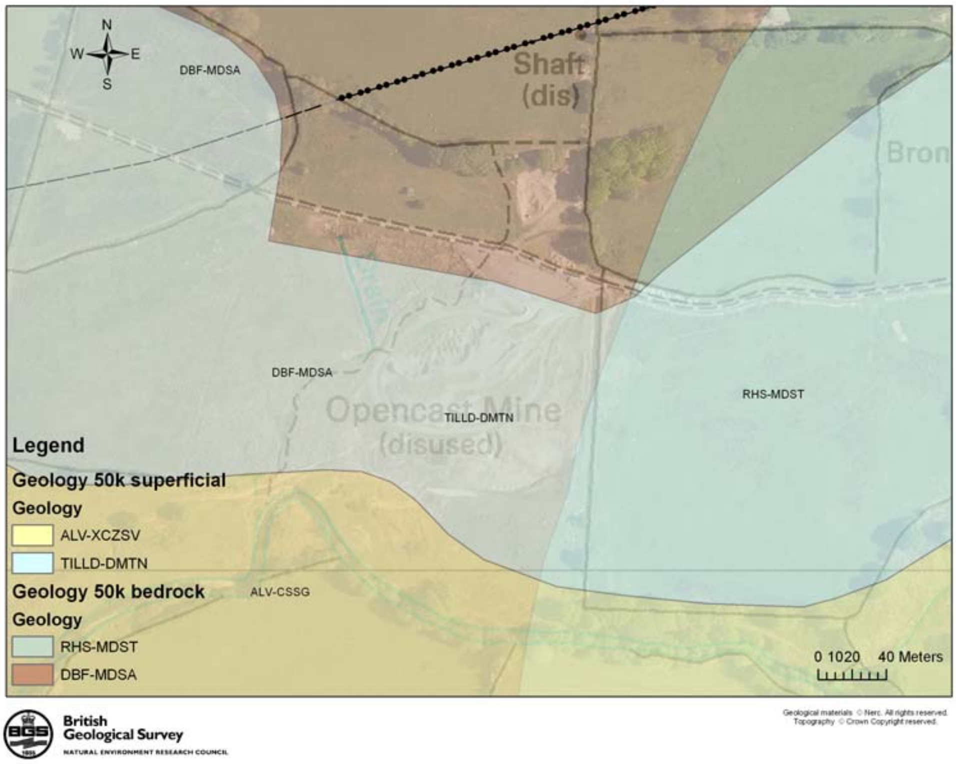

Figure 3 Geological map.

The superficial geology comprises Till (TLLD-DMTN, Figure 3), that is likely to have been derived from the Welsh ice-sheet during the Devensian glaciation, and Alluvium (ALV-XCVZSV, Figure 3). The Till was exposed in a bank adjacent to the river (Figure 4) and was characterised by an upper, paler, more weathered, possibly periglacially affected layer of 1 to 2 m in thickness, underlain by a slightly darker more gravelly lower layer (Figure 4). The boundary between the two layers undulates considerably. Gravels in the lower layer are pseudo-bedded, predominantly subrounded and of medium to coarse gravel grade with occasional cobbles. The clasts are largely locally derived slate and quartz. It is plausible that the upper and lower layers are representative of two different ice sheets, as it is known that the area was overridden by the Welsh and possibly also the Irish Sea Ice sheets during the Devensian glaciation (Davies et al., 2007).

Figure 4 Exposure of Till.

Alluvium was encountered in two areas: i) the near surface soils associated with a spring line at the northern edge of the river flood plain and extending down-slope towards the river ii) adjacent to the river. The field immediately to the west of the abandoned mine area was covered by sedge-like grasses associated with these seepages. It was also exposed by hand augering at a number of locations (Figure 5), including SN 74277 66181 (Figure 6), where 0.80 m of medium brown soft to firm amorphous peat was underlain by soft (becoming firm with depth), bluish-grey silty, clay with occasional peaty rootlets extending to 1.40 m depth. Closer to the river the near surface alluvial soils were found to comprise firm grey silty clay with occasional yellowish brown staining and rootlets (SN 74202 66065) and about 20 cm of firm grey mottled reddish and orange brown silty organic clay river bank deposit (SN 74227 66028, Figure 8) overlying 55 cm of firm grey mottled brown and orange brown silty clay with pockets of fine to medium and occasional coarse gravel grade tabular clasts of mudstone resting on subangular to subrounded medium to coarse gravel and cobble grade tabular bedded gravels that grade into the river bed.

Figure 5 Location of alluvium exposure as noted in the text. (Aerial photography © Getmapping Licence No. UKP2006/01).

Figure 6 Peat underlain by bluish-grey silty clay in a marshy area to the west of the site (close to SN 74277 66181 in Figure 5).

Figure 7 Detail of Figure 6 showing orange brown seepage in the ditch.

Figure 8 Alluvium, showing iron enrichment associated with seepages to the river.

4 Hydrogeology

The Devil's Bridge Formation is classified as a minor aquifer, which is dominated by fracture flow in otherwise relatively impermeable strata. The highest transmissivities would be expected close to fault zones and in the weathered bedrock (Shand et al., 2005). Field evidence (29 March 2012, Figure 2), comprising bedding plane seepage in the vadose zone at the back of the quarry immediately to the north of the abandoned mine site, confirmed the presence of fracture flow in the Devil's Bridge Formation. Research, comprising hydrochemical monitoring and modelling in the Plynlimon catchment (Haria and Shand, 2004) suggest that bedrock groundwater can be an important component of streamflow with a significant influence on stream chemistry. The results of this research indicate that recharge processes are likely to be more complex than a simple routing via soil water, or displacement of "old soil water". Instead, it is more likely that there are a number of flow paths, which include: vadose flow to bedrock groundwater compartments with different travel times and groundwater chemistries; surface and groundwater mixing and recharge via a number of pathways, including soil pathways. In the case of this site the situation will be further complicated by a number of possible flow paths through the Till and Alluvium, as well as the mine spoils, which will impact on the groundwater chemistry.

It is likely, as noted by ExCAL Limited (1999), that the hydraulic gradient across the site is to the south, towards the river, however this may be locally interrupted by the underground mine workings.

Whilst percolation is likely to be minimised through the Till and Alluvium as a consequence of the particle size distribution, evidence suggests that there is seepage through both of these superficial deposits. The Till was characterised by an upper, weathered, possibly periglacially affected layer with evidence of leaching (white carbonate precipitates), particularly in the upper layer of the Till. The influence of the presence of carbonate minerals in the superficial deposits on the groundwater chemistry of the Teifi catchment has been noted (Shand et al., 2005).

The ExCAL report indicates that the mine shafts are open. This is in keeping with information provided by Richard Shaw (personal communication, April 2012).

Jones (1922) reported that the adit intersected the lode at approximately 690 feet OD (~ 210 m OD). This suggests that there is a strong likelihood of groundwater seepage across the site and also to the River Teifi.

5 Hydrology

The upstream catchment area of the Teifi has been determined from the Flood Estimation Handbook CD ROM (CEH, 1999) to be in the order of 31.79 km^2. Rainfall is in the order of 1660 mm (SAAR value, CEH, 1999) and the baseflow is 0.398, so surface run-off is high and the river hydrograph responds quickly to rainfall events.

The surface topography slopes from about 240 m OD at the entrance track to approximately 185 m OD at river level, such that there is a natural southerly flow of surface water across the site. The surface water emanating from the spring line has been managed and is artificially drained via surface water ditches.

A number of river bank seepages were readily identifiable by orange brown staining in the river bank (Figure 9). Many of these seepages are likely to be naturally occurring. However, a number may represent contaminant inputs to the stream. A survey of the physico-chemical parameters of these seepages may help address this uncertainty (section 8).

Figure 9 River bank seepages identifiable by orange brown staining.

During the site visit, which coincided with a prolonged period of dry weather conditions, surface runoff over the spoils was not evident, however signs of seepage at the base of the spoil heaps were observed (Figure 10). A pipe at NGR SN7425066046 (EA site 82970- Abbey Consols Spoil Runoff 2) is collecting a proportion of the drainage for monitoring the flow and quality of the spoil seepage (Figure 13). A boggy area was noted at the base of the spoil heaps (sample AC-7, SN 74262 66075, Figure 11) and upstream EA monitoring point 82970.

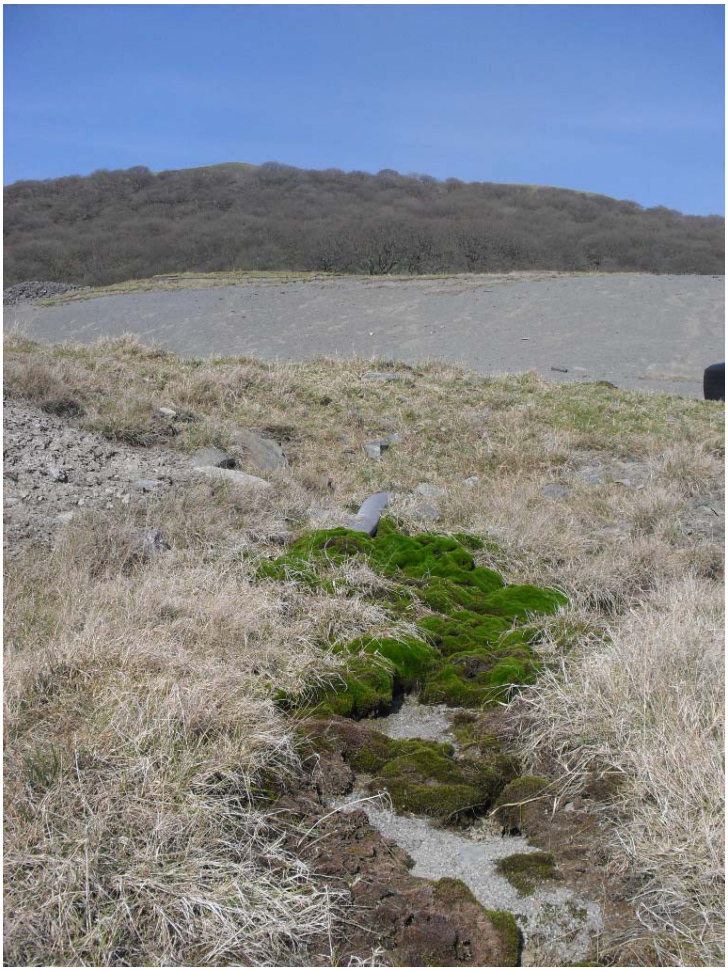

Figure 10 Seepage at the base of the spoil heaps colonised by lichens.

Figure 11 Collection of tailings sample (AC- 7) by hand auger in the marshy area downstream of the spoil heaps. Location is illustrated in Figure 21.

Figure 12 Detail of the marshy area in Figure 11.

Figure 13 Pipe draining the area at the base of the spoil heaps, EA monitoring point 82970.

The presence of an issue near the old quarry area, north of the spoil heaps, at SN 7437 6618, as noted by ExCAL Limited (1999), may represent mine water issuing at this point, possibly entering the mine workings from the north-west area of the catchment. This water is sampled by the EA at SN 274378 266161, ID 82988 “ABBEY CONSOLS D/S ROAD” (Figure 14).

After passing through a road culvert this water flows via a ditch in a southerly and then westerly direction around the site (Figure 15 and Figure 16) and outside the area of the spoil heaps (Figure 17).

Figure 18 and Figure 19 show the drainage from the mine site entering Afon Teifi.

Figure 14 EA sampling location ID 82988 "ABBEY CONSOLS D/S ROAD" at SN 274378 266161. Paul Edwards from EA demonstrating flow measurements.

Figure 15 Ditch to east of spoil heaps (arrowed).

Figure 16 Ditch after it bends around the spoil area flowing in a westerly direction.

Figure 17 View of mine spoil area with pipe collecting water from ditch running to the east of spoil heaps (EA monitoring site 82989). Behind the fence it is visible an additional pipe collecting ponded water (EA monitoring site 82969).

Figure 18 Drainage from Abbey Consols mine entering Afon Teifi.

Figure 19 Floodplain receiving the drainage from Abbey Consols spoil heaps.

6 Spoil heaps composition

The ExCAL Limited (1999) study highlighted the heterogeneous texture of the spoil heaps ranging from coarse gravel to cobble size at the north of the tip near to the historical extraction point, through uniformly graded fine gravel size across the centre of the site, to fine silt and clay fraction at the southern end of the tip, around the treatment area near the river. During the site visit on the 29th March 2012 finer tailings were in close proximity to the assumed processing area on the eastern side of the site, where the burrow and bones were seen.

Extensive sampling was carried out on site as part of the ExCAL survey and location of trial pits mapped in drawings. The trial pit logs are, however, not available in the report.

The study made reference to analysis of the spoil; however, raw chemical data are not available. The report gave length, width, height and volumes for each spoil heap and calculated the mass in grams of Zn and Pb of each spoil, based on chemical analysis and average density for all grades of spoils on site (calculated as 1.8 kg/l).

The estimated total mass of the spoil heaps of 31822 tonnes (ExCAL report Appendix A Site Description) is in accord with the recorded total production of 1236 tons of ‘lead ore’ and 1765 tons of ‘blende’ (zinc ore) noted in Jones (1922). The mine is recorded as working irregular, steeply dipping lenses of lead and zinc ore, probably in a matrix of quartz and host rock fragments along east north-east to west south-west striking lode. A ratio of waste to ore of 10 : 1 would be similar to other mines in the Central Wales Orefield.

During the site visit on the 29th March evidence of desiccation cracks in the area SN 74319 66075 were visible, a sample AC-9 was collected from the 2-3 cm thick friable pale yellow fine silt crust over the tailings. Mineralogical analysis of the samples could indicate the type of metal salts present and inform on the quality of the potential surface runoff during the flush out at the first rainfall after a prolonged dry period.

Figure 20 Desiccation cracks in the area SN 74319 66075 (sample AC-9).

7 Waste/soil augering

Figure 21 and Table 1 give the location and description, respectively, of the samples taken in occasion of the site visit on the 29th March 2012.

Table 1 Grid references of samples of soil and waste collected on the 29th March 2012 during the site visit

Grid Reference	Sample No.	Notes
SN 74277 66181	AC-1	Hand auger specimen 0.00 - 0.80 m: Soft to firm medium brown amorphous PEAT
SN 74277 66181	AC-2	Hand auger specimen 0.80 - 1.40 m: Soft bluish grey silty CLAY with occasional peaty rootlets, becoming firm with depth
SN 74202 66065	AC-3	Excavated from side of ditch: firm grey silty clay with occasional yellowish brown staining and occasional rootlets.
SN 74227 66028	AC-4	River bank: 0 - 0.15 m Grass over firm grey mottled orange brown silty organic CLAY - overbank deposit; 0.15 - 0.50 m Firm grey mottled brown and orange brown silty CLAY with pockets of fine to medium grained, occasionally coarse grained tabular, subrounded clasts; 0.50 m - Medium to coarse gravel and cobble grade subangular to subrounded bedded tablular gravel. Sample from 0.15 to 0.50 m.
SN 74239 66033	AC-5	Hand Auger: 0 - 0.20 m; Soft ot firm greyish brown slightly sandy silty Clay with occasional peaty pockets and rootlets
SN 74283 66106	AC-6	Sample of coarser tailings/ fine rock waste:grey, fine to medium gravel (occasionally coarse gravel grade) slightly silty gravel.
SN 74262 66075	AC-7	Sample of tailings from marshy area (water table few cm below ground): wet, grey, very coarse sand.
SN 74360 66083	AC-8	Grey, mottled bluish grey and orange brown and weathering to brown, sandy SILT grade tailings. Occasional fragments of sheet asbestos at surface.
SN 74319 66075	AC-9	Area with evidence of dessiccation cracking limited to 2-3 cm crust (friable, yellowish, fine silt)
SN 74319 66075	AC-10	Same location, tailings below crust

Figure 21 Aerial photograph of Abbey Consols Mine site with EA sampling locations (red stars) and samples collected during the site visit on the 29th March 2012. Boundary ditch marked in yellow with direction of flow (Aerial photography © Getmapping Licence No. UKP2006/01).

8 Uncertainties in the development of a Ground Model (GM) and recommendations

The development of a conceptual ground model (GM) for the site should form the basis for understanding the potential links between contaminant sources and the key receptor identified as the Afon Teifi, and therefore should be integral to any proposals for remediation. This could best be achieved by preparing cross sections from a site survey. Investment in further investigation should be aimed at addressing key areas of uncertainty in the GM, which are focused on source and pathway characterisation.

Key uncertainties that have been identified include:

Contaminant sources:

The key contaminant sources that have been identified include:

i) coarse-grained mine waste

ii) fine-grained mine waste. There is a possibility of an, as yet unidentified, slime pit which requires further investigation.

Broad figures of the lateral and vertical extent of the heaps have been reported by ExCAL Limited (1999), although greater details should be obtained through trial pits and subsequent mineralogical and geochemical characterisation of a selection of samples. The samples (Table 1) taken during the visit on 29 March should be analysed for confirmation of the previous sampling and to check if the boggy area underlain by alluvium to the west of the site is contaminated (Samples AC1- AC2). Mineralogical analysis of the salt effloresces contained in the fine-grained crust samples (AC 9 & 10) should be undertaken to characterise the temporary contaminant storage represented by these crusts formed during dry periods and model the runoff composition once these salts are mobilised by storm water.

There is also a possibility of iii) a contaminated groundwater source from the mine workings. It would be useful to gain information on:

- Elevation of groundwater levels in the mine workings, which could be achieved through site survey, as we understand the mine to be accessible;
- Mine working plans.

Pathways:

It is suggested that the contamination to the Afon Teifi from the spoil heaps is due to both surface runoff passing over the spoil heaps and by groundwater moving through the spoil heaps to the river. Significant gaps remain as follows:

- Detailed understanding of how surface and groundwater move through the site;
- The location of the adit;
- Surface water courses have been altered and remain unlined; it is uncertain to what extent surface water passing along them drains into the ground;
- Determining the extent of the groundwater contribution to the river, and
- Determining the role of the boggy areas.

To address these knowledge gaps it is recommended to further understand ground levels (undertake a site survey), consider groundwater chemistry and continuity to the river. A geophysical survey might help locate the adit. A survey of physico-chemical parameters at closely spaced intervals along the River Teifi in the stretch extending from upstream to downstream of the site may help identify groundwater contributions to the stream.

Remediation proposals:

The use of French Drains has been recommended by ExCAL Limited (1999); this would have the advantage of cutting-off a component of the groundwater flow, but further information would be required to establish the full depth of any groundwater contribution throughout the site and would also need to consider feasibility of construction in terms of depth to bedrock and excavability.

Capping the site has been recommended. This would increase the rate of surface water flow to the river, which may have potential hydraulic impacts as well as a potential impact on ditch and bank stability. The potential impacts on the surface water quality of the Afon Teifi can only be assessed once more hydrogeological and hydrochemical characterisation has been undertaken.

A concrete capping option would require further consideration in the context of resistance to sulphate.

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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