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The Treatment of Pumped & Gravity Minewater discharges in the UK and an Acidic Tip Seepage in Spain

by

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Abstract

The UK government is presently funding the clarification of contaminated gravity discharges from abandoned mines to improve river water quality. The upgrading of pumped minewater stations has also taken place where increase in discharge has occurred following mine closures. This paper describes three minewater treatment schemes completed by IMC in the UK and a project to treat acidic seepages at a spoil heap in Spain using compost bed principles

The treatment facilities at the former Woolley Colliery in Yorkshire, where minewater containing up to 80 mg/l total iron is pumped from underground workings at up to 200 litres/sec, are described. The improvements to settlement ponds and cascades, the use of cloth filters and the construction of a 1.4 ha wetland to provide tertiary treatment are also discussed.

Two projects to clarify gravity minewater discharges from abandoned drainage adits are now nearing completion. The Bullhouse scheme in Yorkshire is a £1.2M project involving construction of pumping sumps, overland pipelines and a large earthwall lagoon to clarify a flow of 40 litres/sec containing around 70 mg/l iron. The £0.9M Old Meadows scheme in Lancashire involves construction of a pumphouse and overland pipeline, a chemical treatment facility, settlement lagoons and a wetland to provide tertiary treatment.

The project to neutralise acidic seepages is being constructed on the spoil dump at an open pit Lignite mine in Northern Spain with the assistance of ECSC funding. It continues the principles of neutralisation of acidic minewater into acidic seepages by use of compost bed technology as part of the final restoration works. Settlement of suspended solids generated by use of wetlands is proposed.

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1 THE WOOLLEY MINEWATER SCHEME

1.1 Introduction

The Woolley Colliery site is located in Yorkshire about 6 km to the north east of Barnsley. Production at the colliery and use of the central coal preparation plant ceased in 1991.

The Woolley Pumping Station was developed to control the level of underground minewater over about 100 km of abandoned workings in West Yorkshire to prevent the inevitable overflow of potentially contaminated minewater discharges from many ancient drainage adits. It replaced a complex of around 15 separate pumping stations that controlled water at individual mines during coal production. Gravitational flow of minewater underground to Woolley is via a modern system of underground roadways created to facilitate the transport of coal to the mine central coal preparation plant before closure.

Existing facilities at Woolley were adequate to treat minewater at a rate of 40 litres/sec experienced during its operational life. The predicted 500% increase in the volume of minewater to 200 litres/sec when a central pumping station made extension of the treatment facilities inevitable to continue to comply with discharge consent limits.

The options considered by IMC Engineering Consultants (IMC), on behalf of the Coal Authority, to meet these requirements are described. These include improvements to settlement ponds and cascades, the use of cloth filters and the construction of a large wetland to improve the quality of the discharge to consent standards. Further research into the reduction of the ammonia content of the minewater using wetlands is also underway. Photograph No. 1 shows an overview of the whole of the treatment scheme.

1.2 The Pumping regime

Underground water levels at Woolley shaft are maintained between 101-115 metres below shaft top level to prevent increase in quantity of minewater discharges from abandoned adits in the region. The adits at Hazlegreave and Gregory Springs presently discharge low flows of minewater but this would be likely to increase should underground water levels rise. It would be difficult to treat minewater at these locations even if planning permission could be gained.

The pumping installation comprises two pumps having a total capacity of 250 litres/sec. One pump runs continuously and is normally adequate to control the minewater level with the second pump on stand-bye. Pumps, which normally perform alternate duty, require regular changing because of the build up of 'ochre' within the unit and in the shaft ranges. Each pump has a separate shaft range along with breather valves, stop cocks and stop valves. The pump motors operate at 3300 volts and consume 42 amps. The power costs are about £130,000 pa and the maintenance costs £90,000 pa. During the year April 95-96, 4 x 10^6 m^3 of minewater was discharged from the pumping station to the River Dearne.

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1.3 Minewater Quality

The quality of minewater raised at Woolley Colliery, both during it's working life and it's use as a central pumping station has been Ferrous Bicarbonate in nature. The dissolved iron concentration has been up to 100 mg/l, the chloride concentration <2000 mg/l, pH about 6.5 and ammonia 3.5 mg/l. The minewater is almost totally devoid of dissolved oxygen and has an average temperature all year round of 17^{0}C. Treatment procedures, because of the excess of alkalinity, have been confined to simple aeration since the conversion from Ferrous to Ferric iron is rapid.

Since the transfer of the site to the Coal Authority, a gradual decline in the total iron concentration from about 80 mg/l to 50 mg/l has occurred. There have, however, been large fluctuations in the quality with a rise from 60-100 mg/l before the decline became re-established. This diminution appears somewhat more rapid the other minewater pumping stations in the area where, one station in particular, has taken 20 years to decline from 160 mg/l to 50 mg/l. The total iron concentration in the mine during it's working life was about 15 mg/l and it is thought that this value will not be improved upon over many years of pumping. It is therefore likely that treatment of the discharge will have to continue well into the future.

When other pumping stations in the region ceased operation, the minewater gravitated underground to Woolley and the rate of discharge increased from 40 litres/sec to 200 litres/sec. The inadequate treatment facilities then available resulted in an unacceptable impact on the River Dearne with the pronounced 'ochre' plume as shown in photograph No 2. The visual impact was evident for a considerable distance downstream.

1.4 Discharge Consents

A consent to discharge minewater and surface drainage issued in 1987 to British Coal contained the following maximum concentrations;

Suspended solids	80 mg/l	Rate	750 m^3/hr (208 litres/sec)
Volume	17,000 m^3/d	Total Iron	15 mg/l until 4/95 3 mg/l from 5/96

The Environmental Agency revised consent conditions to protect the water quality of the river under the increased pumping regime. The reduction in total iron from a level of 15 mg/l to 3 mg/l was therefore required between May 1995 and May 1996.

1.5 Improvement Works

1.5.1 Improvements to Cascades

Simple concrete step aeration cascades were constructed to give a minimum two-metre free fall with splashing of water to allow oxidation of the ferrous iron by atmospheric oxygen. The alteration of flow through ponds from series to parallel allowed better aeration to be

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accomplished along with improved settlement of ochre because of the reduction in flow velocity.

1.5.2 Removal of redundant pond banks

Earth ponds on the site were approximately square with flow in series through the system. Significant loss in effectiveness occurs due to 'dead 'corners and the constant funnelling through discharge pipes. The removal of dividing banks gave an increased surface area of about 15% and a better shape with a length/width ratio of about 3. The flow regime in the initial ponds was altered to operate in series to halve the flow velocity giving improvement sedimentation characteristics.

1.5.3 Fabric filtration Systems

The primary settlement ponds proved effective in reducing the concentration of suspended solids to relatively low levels. However, in the secondary earth-ponds, the small particle size of the residual solids makes them difficult to settle. A positive filtration system was constructed to remove these fine suspended solids to achieve rapid improvement in discharge quality to comply with consent conditions.

Two fabric filter wall units were constructed to strain the fine suspended solids from the minewater in its passage between earth ponds. Each unit consists of three individual walls through which the minewater must pass, thereby detaining fine suspended solids on the fabric surface. This measure provided an instant and significant reduction in suspended solids concentration to well within consent standards. The filters require regular changing as they quickly become coated with 'ochre'. This labour intensive practice was viewed as s short-term expedient until the 'wetland' matured. A number of filter materials were considered at the completion of construction. Fine geotextile materials were found to be highly effective in straining suspended solids but they very rapidly became impermeable due to 'ochre' coating. Copra mats, which comprise coconut fibres, proved to be too permeable and ineffective in removing suspended iron particles and were therefore unsuitable. The material selected for long term use was waste wool material from local industry that proved to be economical in cost with a site life of 3 days before replacement. The filter changes twice each week were costly but ensured consent compliance thus removing the risk of prosecution.

The maturity of the wetland has improved treatment capability and the use of the filter system has been discontinued although the structures are retained for use during maintenance periods.

1.5.4 The Wetland.

The construction of a wetland was to achieve long-term removal of fine suspended solids from the minewater to meet the higher standards in the discharge consent from May 1996. Photograph No. 3 shows the wetland and the discharge channel. The use of wetlands to treat minewater is not new and they have proven effective at "locking up" contaminants within the sediments, subsoil and the biomass of the plants. Much of the contamination is harmlessly retained within the marshes so that the quality of the water flowing out is substantially improved. Most notably in the United States of America, "man-made" wetlands have been constructed to treat minewater although they have often had to rely on imported organic matter to maintain plant growth and treatment performance.

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1.5.5 Design of the Wetland

The requirements for low cost, sustainable performance, led to the conversion of arable land between the colliery site and the river into a constructed wetland. The results of analysis of soil samples and a site survey confirmed the suitability of this land to form a productive wetland treatment system.

A surface flow wetland using the existing soil as the growing substrate was proposed. A key parameter in the design was a minimum width that needed to be maintained throughout the length of the wetland. This restricted the size of wetland to 1.4 hectares within the total area of arable land available. Surveys showed that relatively little grading was necessary to achieve the required land profile. This both reduced earthmoving costs and more importantly, helped to preserve a good soil structure in which to plant.

In keeping with minimising cost and maintaining visual amenity, the wetland was designed with earth berms seeded with a stabilising low maintenance mix as the main water containing structure. Concrete was only used for the outlet to the discharge ditch and six adjustable weirs were incorporated to allow the water level to be adjusted. The objective was to design a natural feature which would fit seamlessly into the local environmental and provide a wildlife habitat whilst performing it's principal function of minewater purification.

A simple pipe distribution system to spread the flow evenly over the whole 110 metres width of the wetland was devised. This consisted entirely of 300mm plastic pipes carrying water into four distribution zones incorporating 'Tee' fittings. If changes in flow pattern are required this system is easily adjustable and readily dismantled and re-connected.. The plants have been set directly into the existing soil so that the passage of water through the wetland will result in the detention of solids on plant stems and leaf litter. The plants should also achieve a further reduction in any dissolved metals in the effluent. The system requires little maintenance or supervision other than regular review of the growth of the plants and possible addition of fertilisers, although this has not yet proved necessary because of the high levels of nutrient remaining in the soil.

1.5.6 Construction and Planting

Construction commenced in May 1995 and planting was completed within two months. Despite extremely high temperatures during planting, few plants have failed to become well established. Species were mainly pot grown but bare-rooted stock was used in some areas to contrast the rates of growth of each type.

The plants are mainly native species selected to, create visual diversity, and to provide a variety of wildlife habitats. The species were selected from knowledge of plants that naturally become established upon colliery sites, particularly in minewater flows. The species used are:

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Scirpus lacustris (True Bull Rush)

Typha latifolia (Bull Rush)

Typha angustifolia (Lesser Bull Rush)

Phragmites austraulis (Common Reed)

Iris pseudacorous (Flag Iris)

Phalaris arundinacea (Reed Canary Grass)

Juncus efflisus (Soft Rush)

Review of the success of each plant type has been carried out to identify the most prolific species. It is now three years since the wetland was planted and results are very encouraging with many plants up to 2 metres in height. As the plants continue to mature, it is expected that the performance of the wetland will show further improvement. It is also hoped that long-term performance will be maintained from the natural productivity of the site with the need for only minimal imported of nutrients. Photograph No. 2 shows an overall view of the wetland and the outflow.

In contrast to some constructed wetlands, the Woolley scheme has mainly avoided use of concrete structures containing monocultures of plants sustained by imported nutrients. It has been created by exploiting the existing landform and natural resources of the site to provide a low cost minewater treatment system with good visual amenity and diverse wildlife habitats. Planting directly into a prepared field surface without import of sub-strata materials has resulted in a low cost treatment which consistently maintains concentration of iron in the discharge at less that 1 mg/l.

The overall cost of the complete construction of the wetland including inlet and outlet arrangements was less than £5/m^2 which is makes the use of well considered and designed wetland an attractive option.

1.6 Wetland to reduce the concentration of ammonia in the discharge

The concentration of ammonia in the raw minewater is about 3.5 mg/l and there is little reduction during passage through the treatment system. It is thought that since the wetland plants are located in what was highly productive agricultural land providing sufficient nutrients to make reduction of the ammonia unnecessary.

There has been a reduction in the concentration of ammonia in the River Dearne because of improvements at local sewage works. The Coal Authority is looking to the future when reductions in ammonia may be required at Woolley or other sites responsible and are supporting research into the effectiveness of wetlands in reducing ammonia. The research will monitor plants in a gravel substrate within an impermeable seal to ensure no external sources of nutrient, other than the ammonia are available to the plants.

The trial wetland follows the main wetland having an available area of less than 0.5 ha. This will not allow treatment of the total flow although it will allow the loading/unit area to be varied and the resulting reduction recorded. Horizontal flow beds have been constructed because of the lack of fall available on the site. Two beds will be planted with Scirpus

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Lacrustus and two with Phragmites Australis. One bed of each plant type has been composted with peat to provide an anaerobic layer so that the effectiveness of each type of plant and surface treatment can be monitored. The construction of the wetland and planting is completed and Imperial College are carrying out research of the performance of the test site so that the findings may be used to assist future design work.

1.7 Future proposals being considered include:

Construction of a large sludge holding lagoon with capacity for several years of ochre make. This will reduce the significant costs of disposal of sludge off-site and will allow the accumulation of a deposit of material with some economic value.

2 The Old Meadows Abandoned Minewater Discharge

2.1 Introduction

Old Meadows minewater contains significant iron contamination and discharges into the River Irwell near Bacup in Lancashire. The discharge emerges from a 2.1 m x 0.9 m gravity drainage adit and flows directly into the river. 'Ochre' staining of the bed can be seen, on occasions, up to 24 Km downstream but in normal conditions, the discharge has a significant effect on about 6 Km of the river downstream of the discharge. The Adit is located in the bottom of a steep sided valley whilst the site for the proposed treatment plant is situated on a sloping plateau about 40 meters above. The landscape is of a rural nature, the upland pasture being used for the grazing of sheep and cattle.

2.2 Minewater Flow & Quality Data

Monitoring undertaken over a relatively short period during a protracted period of dry weather. The minewater treatment plant design is based on a discharge rate of 57 litres/sec compared with the maximum flow rate recorded of 50 litres/sec. The maximum analysis available for total iron contained 37 mg/l and this has been used to determine the treatment plant design. The discharge contained a cold acidity (to Phenolphthalein) of 70 mg/l as calcium carbonate. Quality data is shown in table No. 1.

Table 1 Water Quality data

Parameter	Required EQS	Value in Discharge	Value in Watercourse	Discharge Flow Rate	Watercourse Flow Rate	Loading Kg/day	Reqd. Value
pH	6 - 9	5.9	6.6	57 l/s	36.4 l/s	-	-
Total Iron	1 mg/l	37 mg/l	-	57 l/s	36.4 l/s	304	1.0
Acidity	-	70 mg/l	<2 mg/l	57 l/s	36.4 l/s	575	-
Net. Acidity	-	Nil	-	57 l/s	36.4 l/s	Nil	-

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The Environment Agency require the treated minewater to be returned to the River Irwell with a total iron of <1 mg/l to achieve a EQS of 2 mg/l. However, the consent will be a descriptive consent related to an agreed method of operation of the site to allow the desired water quality standards to be achieved.

2.3 Methods of Treatment Considered

There are two principal methods by which this minewater can be treated:

- By chemical neutralisation, settlement and tertiary treatment
- By neutralisation and sedimentation using a wetland

The area required for wetland treatment (*Heldin et al 1994, Younger 1995*) is 3 Ha. for a net alkaline water using an iron loading of 10 g/m^2. To remove acidity at a loading of 3.5 g/m^2, the area required would be around 16 Ha. Such an area is not available and therefore the use of wetland alone is not applicable. If the minewater is first neutralised with settlement of ochre solids on a wetland, the area required would be about 3 Ha which is also not available.

The potential sludge loading, estimated at $8m^3$ per day, if applied directly onto the bed, could rapidly cover the the plants and hinder establishment. Process selection is, therefore, of chemical neutralisation of the discharge, sedimentation in lagoons followed by tertiary treatment using a surface flow wetland to meet a discharge of 1 mg/l total iron.

2.4 Construction Details

Figure 1 shows the layout of the treatment scheme from the adit to the treatment area.

2.4.1 The Adit

Photograph No. 4 shows the adit which is located adjacent to the river. A stopping wall will be constructed in the free drainage adit to a height of 1.2 metres to provide flow balancing storage volume into which the pump suctions can operate. Twin 300 millimetre diameter ranges lead for 200 metres from the adit directly to the underground sump in the Pumphouse, the down gradient allowing the pump sections to be submerged. Control of the pumping regime will be by electronic level detectors in the adit which will maintain a constant depth of water of around 800 millimetres in the adit by varying the pump speed and output to the treatment site. Should sudden surges of minewater occur, due to collapses or other features in the underground workings, an emergency overflow directly to the river will be provided. It is thought that such instances occur on average once a year.

2.4.2 The Pumphouse

The Pumphouse contains two duty pumps and one standby pump. Each pump has the capacity to discharge 40 litres second and is connected to a 160 millimetre diameter delivery range which conveys water to the chemical dosing station located 40 metres above on the high plateau about 300 metres away. Monitoring of the treatment plant will be from the pumping station by means of a PC with a modem link. A major 6 m high gabion wall has been constructed to gain the space necessary for the pumphouse and access road as shown on Photograph No. 5

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2.4.3 The Chemical Treatment Building

The chemical treatment building is located adjacent to the settlement basins and the wetland on the plateau above the Adit. The use of hydrated lime fed from a silo was precluded because of the visibility of the silo in the landscape of the area.

The Sodium Hydroxide dosing plant selected consists of a bulk storage tank having a minimum capacity of 18,000 litres and an anticipated usage of 10,000 litres per month.. A transfer pump linked to level probes in the dosing tank delivers to the caustic solution plant on demand. The bulk storage tank, transfer pipe range and dosing building are to be heated when the ambient temperature falls to 10°C. to ensure that the Sodium Hydroxide does not freeze during the severe winters which can be experienced on this exposed site.

A flow measurement device will sense delivery of minewater and switch on the treatment system. This precaution caters for pump failure situations when caustic soda is not required in the system. Normally, a pH probe will measure the acidity of the treated minewater and adjust the quantity of caustic input into the raw minewater. Injection of caustic soda solution will be by four peristaltic or diaphragm dosing pumps which are mounted in pairs over two 100 litres bunded plastic storage tanks situated inside the dosing building. Dependant upon demand one or all of the pumps could be in use at any one time. Safety is paramount and the requirement for decontamination in-case of accidental spillage and the restrictions on storage and filling of chemicals imposed by the supplier have been incorporated.

2.5.4 Sedimentation Basins

The basin design ensures that the appropriate overflow rate is provided so that the settled effluent meets discharge quality requirements. A further consideration has been to maximise sludge retention capacity to minimise the frequency of desludging by constructing as large a pond as possible within the available site area.

Twin sedimentation basins have been excavated on the plateau area following a balanced cut/fill exercise. The ponds are not identical in size because of topographical constraints but they will operate in parallel with flow being proportioned in relation to their surface area. The larger basin is 100 m x 28 m and 3 m deep giving a capacity of 6200 m^3. The second basin is 60 m x 28 m and 3 m deep giving a volume of 3500 m^3. Inlet and outlet weirs on both lagoons will spread flow of water through the basins.

The base and sides of the ponds are in coal measure sales which are essentially impervious although a minimum of 300 mm of clay will be placed and compacted on these surfaces to ensure that water does not leak into sub-strata. This clay used has a low shear strength and is unsuitable for embankment construction but is ideal for sealing purposes.

2.5.5 Wetland

The wetland will be a surface flow system without the import of any substrate. Surplus clay materials will be placed and compacted to form a level impermeable base to the wetland which will be 2000 square metres in area. A minimum of 200 millimetres of soil excavated from the site will be placed over this clay to provide a growing medium for the wetland plants. Because

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of the exposed location of the site, Typha Latafolia and Juncus have been selected because of their durability and suitability in metal laden waters.

The wetland provides tertiary treatment to the expected inflow which should not exceed a total iron concentration of 5 mg/l of very fine solids. Passage of this minewater through the plants will result in detention of fine iron solids on the plants and the leaf letter to enable a final discharge quality of around 1 iron to be achieved. Discharge of the final effluent from the wetland is directly back into the River Irwell.

2.6 Maintenance Desludging

Contractors will undertake maintenance of the caustic dosing plant. Other minor maintenance such as checking the level of caustic soda in the bulk storage tank, cleaning the pH probes, cutting of grass and checking the security of the site will be undertaken by semi-skilled staff on a weekly basis. Annual desludging of 'ochre' solids would be undertaken by contractors using road tankers. It is probable that this 'ochreous' sludge will be transferred about 5 Km. to the proposed treatment site at the former Deerplay Colliery to be dewatered in prepared drying out bays before final disposal.

3 BULLHOUSE MINEWATER PROJECT

3.1 Introduction

The Bullhouse Minewater Project which is valued at £1.1M, will restore the quality of 6 Km of the River Don in Yorkshire which is severely downgraded by the discharge from the abandoned Bullhouse Adit. The minewater contains up to 70 mg/l total iron at a pH around 6.0. The discoloration of the iron detracts from the amenity of the river for a considerable distance and contrasts with the stretch immediately above the adit discharge which sustains a flourishing trout fishery.

The works, which are shown in outline on Figure No. 2 will collect the water discharging from the adit in a underground tank. Pumps will then discharge the minewater for treatment in Bullhouse Quarry through overland pipelines 850 metres in length. Aeration & sedimentation of the minewater will take place in a large earth lagoon constructed in the quarry as part of the restoration of the site. The treated minewater will be returned to the river at the adit site by second pumping installation.

A two-year research project into the treatment of minewater by Imperial College, London will take place to improve understanding and techniques of minewater treatments.

3.2 Construction

The commencement of construction works on the project was in spring 1997.

3.2.1 Overland pipeline

The initial works involved the excavation and placing of the overland pipeline system to connect the pumphouse at Bullhouse Bridge to the treatment site in Bullhouse Quarry, a

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distance of about 850 metres. The system comprises twin delivery pipelines of 160 and 200 mm diameter and a return water pipeline of 200 mm diameter. The pipelines were placed at a nominal depth to of 1200 mm invert and a granular bed and surround protects the system. Hatch box access points were fixed in manholes at 100 metre intervals to allow access into the pipeline to enable jetting of ochre accretions to be easily accomplished to maintain the full minewater flow. Progress in pipelaying across agricultural land was rapidly achieved although a significant delay in purchase of the former railway track imposed a four-month delay before completion of the full length of the pipeline was achieved.

3.2.2 Minewater Treatment Lagoon

Construction of the minewater treatment lagoon in Bullhouse Quarry commenced in summer 1997. The lagoon involves the construction of a earth-lagoon having a capacity of 50,000 cubic metres and a surface area of about 6,000 square metres in the quarry void. The depth of lagoon is 8 metres. The lagoon was constructed under the Mines and Quarries Act 1954 and the Mines and Quarries Tips Regulations 1971 and was based on the technical requirements of applied by the former British Coal for the construction of Tips and Lagoons.

The construction works involved the excavation and placing of 140,000 m^3 of coal measure sales and superficial clay deposits that formed the backfill in the former Hepworth Building Products Quarry. Close selection of materials took place throughout the earth moving contract to ensure that impermeable materials were used to form lining seals to retain water in the lagoon whilst more permeable spoils were used either to provide drainage layers or as support to the heavily compacted seals. Placing of the seals was in layers 300 mm thick subjected to compaction by a heavy vibrating roller. Permeable materials and drainage layers were placed in one metre thick layers with a lesser degree of compaction being applied. The whole of the structure had been subject to a detailed geo-technical analysis to ensure that minimum factors of safety against failure of 1.5 would be achieved.

Excavation of materials was by tracked excavator loading dump trucks to transport the spoil to the point of placing where spreading and compaction was achieved by bulldozers towing vibrating rollers. Heavy inflows of ground water into the excavation limited the depth of the lagoon to less than that anticipated. The shortfall of material required a revised profile to be engineered for the restoration of the quarry which generally involved the inclusion of berms into the profile to reduce the amount of fill necessary to achieve a high standard of restoration.

Restoration of the site was completed by the placing of 400 millimetres of soil materials over the slopes of the lagoon. A full planting scheme was completed as the final step of the restoration of the lagoon area. About 20,000 native species of trees have been planted on the slopes which will in future years allow the area to present a pleasing vista to pedestrians using the adjacent Trans-Pennine footpath. Photograph No. 6 shows the completed lagoon prior to completion of landscape planting.

3.2.3 Building Works

The construction of the delivery and return water pumphouses and the inlet cascade aeration system commenced at Easter 1998. Initial work was at the raw water pumphouse involving the excavation of a sump 6 metres in depth adjacent to the River Don was difficult because of the heavy inflows of ground water which were encountered. The contractor employed a large

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settlement tank to control discharge quality whilst he completed the concrete blinding of the base of the excavation which significantly reduced the volume of inflow.

The underground storage volume is constructed in reinforced concrete and comprises twin tanks, each 15 metres in length and 3 metres in width. The height of the tanks are about four metres with the top being 2 metres below finished ground level in an area which will be restored to pasture land. The tanks provide a storage capacity for the inflow of water from the adit of between two and three hours and provide a safeguard against overflow of untreated discharges in the event of power failure. The pumping equipment is located below ground level in a dry well and on completion of a construction and restoration, only a stone built pumping station about 5 metres square will be visible above ground level.

The return water pumping station comprises a simple stone building housing the pumps. The storage capacity for these pumps is provided in an existing earth walled lagoon used as a balancing sump. The return water will be discharged to the point of abstraction about 800 metres distant being returned through the overland pipeline system.

The inlet system to the lagoon uses the level difference between the rail track and the lagoon for a cascade aeration system to oxidise the raw minewater. This comprises a six-metre high reinforced concrete manhole constructed adjacent to the rock face which forms the northern perimeter of the quarry. By alternating the position of access hatches on landing stages, a simple means of aeration of the minewater is achieved. Consideration has also had to be given to the ingress of air into the manhole system, security to prevent unauthorised access and the provision of means of jetting clear ochre deposits at regular intervals. Distribution of water from the cascade into the lagoon is by plastic pipe work arranged to spread the flow over the full area of the lagoon. Intermediate manholes allow the research contractor access for measurement of water flow and quality or the introduction of chemical treatment.

3.2.4 Mechanical and electrical works.

Six pumps will furnish the raw and return water pumphouses. Each pump will be identical comprising 40 litres/second centrifugal types to provide an economical and reliable solution to the pumping of minewater on the scheme. Five pumps will be installed and will be available for operation whilst the sixth pump will be maintained as a spare. Since all pumps are identical, the ability to switch pumps should limit the potential down time.

In the raw water pumphouse, two pumps will be installed to pass pump the water through the overland pipelines. A third pump will recirculate water in the raw-water storage tanks through a system of submerged pipes containing jets to maintain ochre solids in suspension. This will minimise build up of solids in the sump and assist their being pumped overland to the quarry for settlement. A further advantage of this system is that turbulence caused will assist the oxidation of the raw minewater and help to reduce accretion of solids in the pipeline.

The return water pumphouse contains two pumps on a duty and standby basis, both connected to a single overland return water pipeline. The adjacent polishing pond which is elevated above pumphouses provides a positive flow unto the pump suction as well as a flow balancing element for the return water clarified in the main lagoon. The security of systems in the pumphouses will be monitored by a PC and modem in the raw water pumphouse with data transferred by radio link to a remote control room.

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The normal mode of operation of pumps will be to maintain a minimum level of water in the sumps at both pumphouses to enable the flowbalancing element to be available to prevent discharges of contaminated water to the river in the event of short power failures. Monitoring of the water level in the sumps will be linked to the operation of the pumps by an electronic control giving the ability to vary the speed of operation to maintain a constant water level.

3.2.5 Liaison between construction & research

Imperial College, London will be carrying out research to improve methods of treatment of minewater. The success of the scheme, particularly in its ability to allow maximum flexibility to vary parameters in the research phase depended upon close co-operation between the design consultant and the research contractor. The scheme now incorporates the options to introduce monitoring or addition of chemicals wherever feasible and the capacity to vary operating modes. During the research phase, the same co-operation will be essential to engineer changes to the lagoon & mechanical systems to ensure that the integrity of the system is not compromised and that cost-effective construction methods continue to be adopted.

The formal opening of the project will take place in September 1998 when the research work on minewater treatment can commence for a two-year period.

4 LIMEISA MINE, SPAIN

4.1 Introduction

The mining operation at Mierama, North West Spain, wins over 2 million terms of Lignite each year by open pit extraction for use in the adjacent power plant. The operation involves the excavation of significant volumes of overburden material which is tipped onto a spoil heap, constructed using a stacker.

The crest of the tip essentially forms a large plateau with the western and northern flanks graded to 1 in 2 slopes down to a valley. Surface water drainage accumulates in to valley features running north to south along the plateau of the tip. A number of highly acidic seepages from within the body of the tip also drain to these valleys can be seen on Photograph No. 7. Natural colonisation of the wet areas in these valleys by Typha Latafolia has occurred and consequently, some natural remediation of water quality occurs. This remediation is, however, not sufficient to meet discharge standards and a chemical water treatment complex is operated to neutralise the acidity and precipitate dissolved metals.

The life of the mine is now less than 10 years when reclamation and restoration of the site will be completed. The acidic drainage from the tipping site will continue for many years and a solution to address remediation of the quality must now be defined. The continuing operation of the water treatment complex at a fully restored mining site with no source of income is not a viable consideration and an alternative solution is sought to meet discharge standards at a minimal cost not requiring significant manual input. Passive means of treatment using bio-remediation techniques appear to offer a viable solution to deal with this problem.

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4.2 Remediation using Passive Means using SAPS

Various schemes in the UK and elsewhere have confirmed the findings of Hedin and others concerning the ability of wetland plants to neutralise acidity in a discharge. Whilst plants are able to achieve this objective, the area required is often excessive and beyond that available in the steeply sloping topography. The design concept at Limeisa is to reduce the area of wetland planting to that which can physically be located at discharge sites. This requires that acidity in the effluent be significantly reduced, or eliminated, so that the tertiary wetland is only required to polish the discharge simply by the retention of suspended solids.

The use of limestone drains to neutralise acidity in mining discharges has been used for many years. The concept is simply to place lump limestone in drainage channels and allow the flow of effluent to pick up alkalinity by dissolving the stone. Unfortunately, this effect is short lived since armouring of the stone by the formation of iron solids on surfaces quickly coats the stone and significantly reduces the effect.

Further development to reduce armouring involved the use of passive anoxic limestone drains. In this system, the limestone drain is placed below ground and sealed from the atmosphere in a trench by a compacted layer of clay. The acidic effluent then passes through the limestone drain in the absence of atmospheric oxygen and consequently, the coating of the stone by iron hydroxide is significantly reduced. However, the presence of dissolved oxygen in the effluent continues to promote coating of the stone. The presence of significant levels of aluminium in the effluent is also detrimental to the active life of the stone element as has been shown from experience at the former Wheal Jane Mine treatment system in Cornwall, UK.

Means to further enhance the life of passive limestone drainage systems have been proposed by Kelper and McCreary. The concept, called sucessive alkalinity producing systems (SAPS) uses a compost bed through which the acidic effluent is passed prior to entry into the limestone drain element of the system. Micro-biological action in the anaerobic bed, which may comprise stable or farmyard manure mixed with chopped bark, removes the dissolved oxygen from the effluent in passage through this layer. A reduction in the level of sulphate and aluminium is also to be expected

This gives two significant benefits:

1. The system can to operate for many years without active intervention or significant expenditure in maintaining the system.

2. The acidity of the effluent is significantly reduced or even eliminated and as a consequence, the area of a subsequent wetland is reduced.

This system offers significant benefits to the treatment of acidic discharges from old mines and for treatment of acidic seepages is from mining spoil dumps by a system which can be readily incorporated into a final restoration scheme.

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4.3 Recently constructed SAPS system.

The construction works are now nearing completion on a SAPS treatment system for two discharges in the Pelenna Valley in South Wales ,UK, which has been significantly affected by gravity discharges of minewater from abandoned coal workings. The minewater discharges are generally of low pH (5.0-6.5) containing permanent acidity at flowrates up to 20 litres/sec average containing total iron concentrations of around 20 mg/l. Neath Port Talbot Borough Council have been advised on this project by Dr P L Younger of Newcastle University who devised and provided the outline design concept to the councils' 'in-house' team who engineered and supervised construction of the works.

The Gwenffrwd discharge, which varies in flow rate from 42 litres/min to 2000 litres/min is a good example of application of SAPS technology. The discharge is generally moderately net acidic with a mean net acidity of 19 mg/l as CaCO3 and a mean total iron concentration of about 10 mg/l. As the discharge contains dissolved oxygen and ferric iron when it emerges from the wetland, an anoxic limestone drain was not thought appropriate (Hedin et al 1994) since armouring of stone would rapidly occur.

Minewater contact with limestone will be in a SAPS constructed to accept 25% of the design flow of 225 litres/minute with a 14-hour retention time. This concept was selected for the design because of the low acidity of the effluent. The SAPS should provide more than 80 mg/l of alkalinity compared with 17 mg/l required and will be re-mixed with the other 75% of the flow. This SAPS has a total bed volume of 1250 m^3 of rounded limestone to ensure a design life of about 30 years allowing for the fact that the limestone will gradually dissolve. (Hedin et al 1994). As the limestone cobbles are packed to a thickness of 0.5 metres (Kelper and McCreary 1994), a total surface area of SAPS of about 2500 m^2 has been provided. The overlying anaerobic bed above the stone comprises a mixture of tree bark and farmyard manure. The hydraulic design of the system maintains supernatant water over the compost layer at all times.

4.4 Application at Limeisa Spain

The concept of SAPS as applied to minewater drainages in UK and USA will be applied to the acidic tip seepages at the Limeisa Mine. Seepages from the tip occur into two separate valleys giving a total flow of about 200 litres/min at each location. To collect the seepages from the various points of emergence along the valley requires that the treatment systems be constructed at end of the valleys adjacent to the crest of the tip.

The sealing of SAPS to prevent infiltration into the spoil heap, which would be detremental to stability of the steep tip slopes, is of importance. The arrangement proposed for the SAPS is shown on diagram XX. It comprises a limestone bed probably 1000 mm in thickness overlain by a compost bed 500 mm thick. The compost comprises a mixture of farmyard manure and tree bark although other readily available materials in the local region are being sought.

The area of SAPS required for a flow of 200 litres/min with limestone 500 mm thickness is 2200 m^2. The maximum net acidity as $CaCO_3$ is only 50 mg/l and as a limestone bed can be expected to contribute around 80 mg/l from 14 hrs retention (Younger) the area required could be reduced by 50%. Increase in limestone thickness to 1000 mm could effect a further 50%

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reduction. SAPS 10 metres wide and 50 metres long can be located into the narrow valley features on the tip.

An area of surface flow wetland will be constructed to detain suspended solids generated as a result of the neutralisation of the acidity in the drainage, although analysis shows that the concentrations of dissolved metals are small. The major flow on the wetland will be as a result of surface water run-off following storms and the design must seek to ensure that detained solids are not flushed from the bed by storm flows.

It is envisaged that a stacked SAPS system will be constructed at one of the valleys whilst a surface flow compost bed followed by surface flow wetland will be located at the other valley. The relative success of each system can then be determined. A typical layout of the system proposed is shown on Fig No. 3.

Construction of the SAPS and wetlands will be completed in the summer of 1998 with monitoring of the system being carried out for up to two years. The results of the study will be published and design guidance established to assist other mine operators within the EC to resolve similar problems.

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Younger P L Personal Contact.

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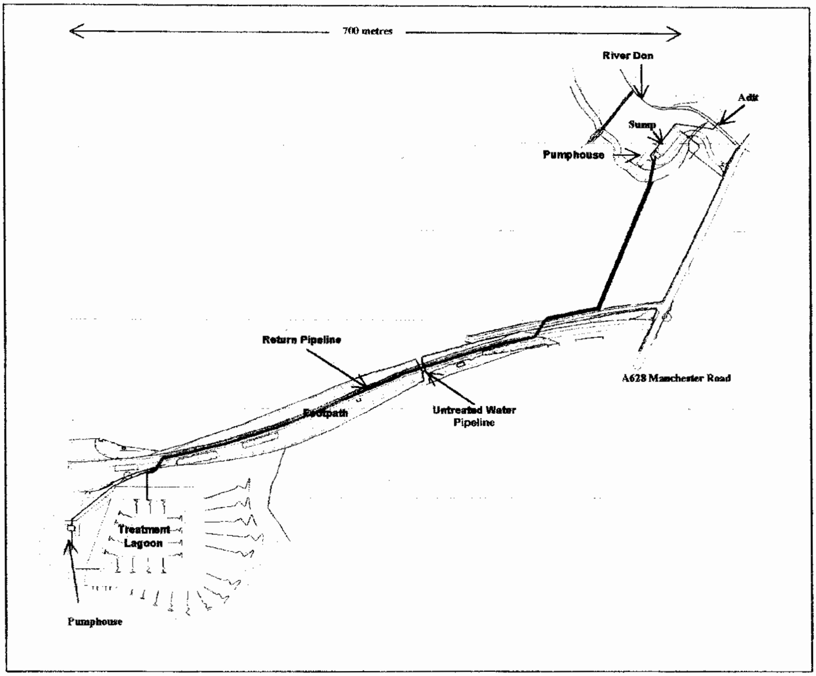

Figure 1 Bullhouse layout Plan

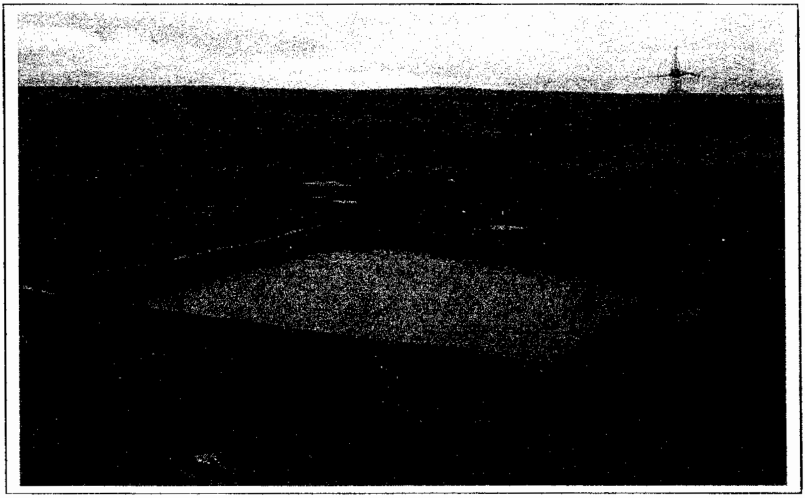

Photo No. 4 The treatment lagoon in Bullhouse Quarry

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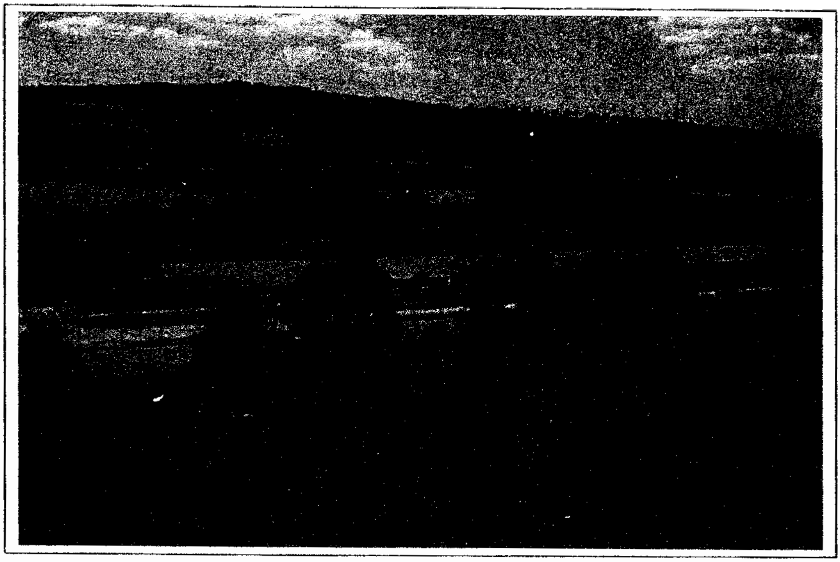

Photo No. 1 Overview of the Woolley site

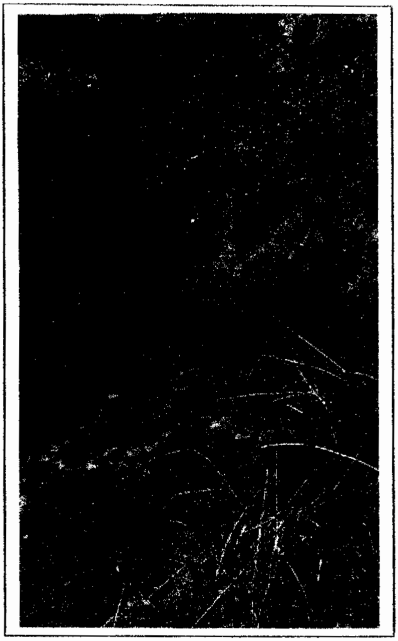

Photo No. 2 Impact upon the River Dearne

Photo No. 3 The Wetland

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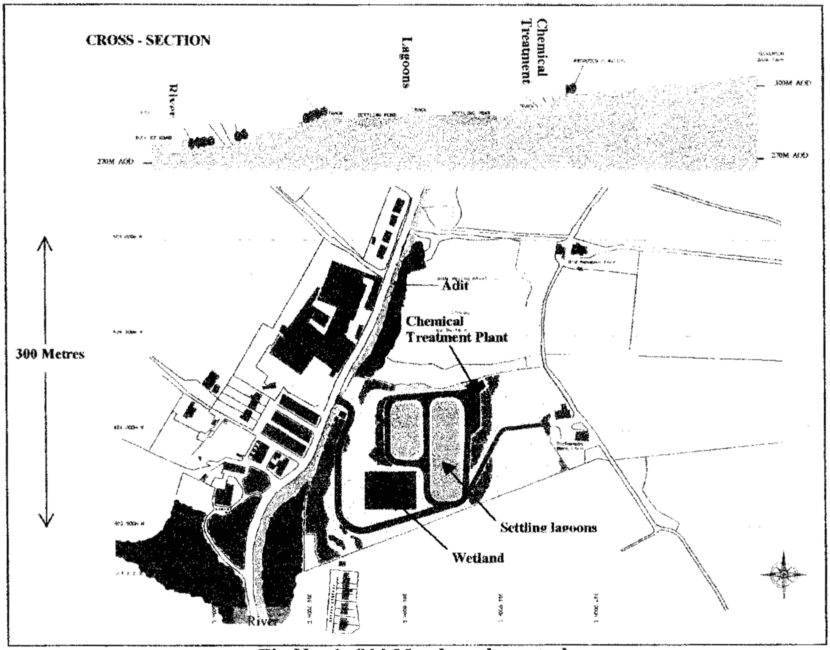

Fig No. 1 Old Meadows layout plan

Photo. No. 4 Old Meadows Adit

Photo. No. 5
6 metre Gabion retaining wall

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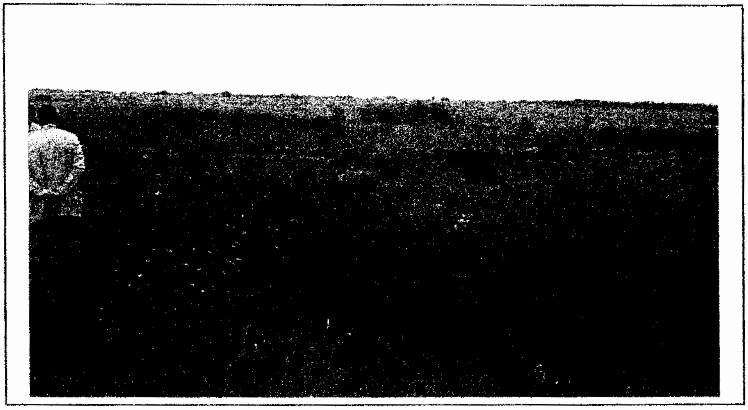

Photo No. 7 Seepage area on Spoil Heap

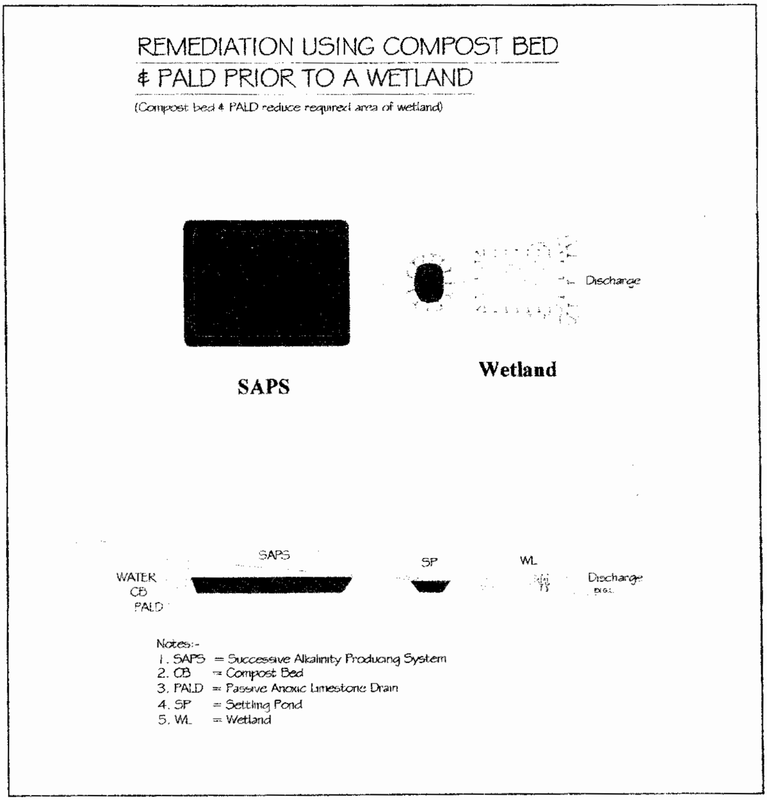

Figure 3 Typical SAPS

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