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MINEWATER REMEDIATION IN THE UNITED KINGDOM

Keith D. PHILPOTT[1]

Abstract. The author will outline the history of minewater remediation in the UK with special reference to investigations and construction schemes undertaken by SRK in England, Scotland and Wales over the past seven years. The influence of mining and geology on the waters, the flow of minewater and its discharge location, and then the subsequent choice of remediation methodology, site and construction option will be examined at specific sites. At Polkemmet Colliery in Scotland rising minewater was prevented from discharging in an uncontrolled manner by installing pumps into an old mine shaft and constructing a semi-active treatment plant on site before discharging the water to a nearby stream. Edmondsley remediation scheme in County Durham involves the treatment of a ferruginous discharge from a drainage adit by the pumping of minewater through a woodland nature reserve up to a three cell wetland, and then by gravity return to a nearby stream. In Derbyshire, the Fender scheme has recently been constructed and involves treatment through reedbeds sited on former colliery and ironworks tips with the water first being pumped across an existing river from shafts sited in the yard of a factory unit. At Blaenavon construction has recently commenced. The scheme involves the capture and piping of two ferruginous minewater flows underground and then treatment through reedbeds. The water flows through Big Pit, a former mine reopened to the public as a tourist attraction.

Key words: minewaters, discharge, environmental, United Kingdom.

BACKGROUND

Minewater remediation within the UK coal industry has inevitably become a major issue over the past decade given the scale of underground mine closures in the 1980's and 1990's and the resultant high political profile of the many issues surrounding the decline of a once large industry. Most of the remediation work has taken place since the privatisation of the industry at the end of 1994 just prior to which the Coal Authority (CA), a Non-Departmental Public Body (NDPB), was set up by central government under the Coal Industry Act 1994. Work by the National Rivers Authority (NRA), another government body, in 1994 identified over 300 discharges from mines impacting some 200 km of river course. Of these, approximately 70 discharges were identified by the regulatory bodies as warranting further investigation. A close working relationship has been established between the CA and the NRA's successor bodies, the Environment Agency (EA) in England and Wales and the Scottish Environmental Protection Agency (SEPA), based upon Memorandums of Understanding signed in 1995 and more recently in 1999. The original document outlined the two bodies respective roles and the exchange of information required in trying to fulfil what was known as the Strathclyde commitment. Lord Strathclyde, in a debate leading up to privatisation, outlined the Government's expectation of the CA in this area:

"The Government will expect it (the CA) to go beyond the minimum standards of environmental responsibility which are set by its legal duties in these areas and to seek the best environmental result which can be secured from the use of the resources available to it for purposes …"

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[1] Principal Geologist, SRK Consulting (SRK), Hamilton House, Kestral Road, Mansfield, Nottinghamshire, NG18 5FT, United Kingdom

LEGISLATION

Under the legislation (S.89(3) of the Water Resources Act, 1991) a person was not guilty of the offence of causing or knowingly permitting the pollution of controlled water if he was merely permitting a discharge from an abandoned mine.

In 1995 The Environment Act contained provision for the repeal of S.89(3) of the Water Resources Act (WRA) 1991. It amended two provisions of the WRA 1991 Act:

- section 58 inserted new sections 91A and B and these require operators to give the EA six months notice of their intention to abandon a mine or part of a mine;
- section 60 amended sections 89 and 161 WRA 1991; the former removes the statutory defence to a water pollution prosecution from owners and operators if the mine was abandoned after 31st December 1999; the latter provides for the recovery of costs and worked notice provisions.

These amendments were brought into force on 1st July 1998 by the EA 1995 (Commencement No. 11) Order 1998. There are exceptions in cases of emergency regarding “danger to life or health” only. The contents of the notification to the EA by the mine’s owner or operator are contained in the Mines (Notice of Abandonment) Regulations 1998 and contain the following:

- details of company, owner and operator,
- nature and date of intended abandonment,
- location of mine, seams, depths etc,
- volume of water discharged for at least the past two years and until projected abandonment,
- latest chemical data for water,
- proposals for future monitoring of groundwater levels and chemistry,
- any actions or proposals regarding anticipated future discharges,
- flooding of underground workings, migration to adjacent mines, recovery levels and times, potential flooded areas and water courses which will be affected.

THE ROLES OF THE COAL AUTHORITY AND ENVIRONMENT AGENCY

During 1995 the concept of prioritising the discharges (based on environmental impact) was introduced, having been developed originally in the Welsh Region of the NRA. Since then multi-attribute techniques, based on monitoring results from discharges, have more recently been combined with various social factors, such as proximity to housing, amenity and recreation areas in order to draw up a “priority hit list”. This is revised annually. The 1999 Memorandum of Understanding between the CA and EA/SEPA sets the following objectives:

- seek to prevent new polluting outbreaks,
- enhancement of the environment by remediation of existing discharges on a prioritised bases,
- the provision of a coherent operational framework to fulfil the above,
- seeking to ensure operators deal with potential pollution from closure of licensed coal mines in a responsible manner,
- furthering the understanding of the processes involved in minewater rebound and sustainable prevention and treatment of minewater pollution.

The Coal Authority now recognises four key activity areas which cover discharges from initial identification through to the completion of remediation schemes. These comprise:

- Monitoring Programme — existing discharges and underground water levels are monitored and evaluated to establish the need for preventative or remedial action;
- Preventative Programme — where pumping schemes and the advance planting of reedbeds are implemented to prevent future pollution;
- Remedial Programme — to progress works to reduce pollution at significant discharges identified as priorities under the monitoring programme;
- Operation Works — under which completed schemes are maintained and managed.

PLANNING PERMISSION AND LAND ACQUISITION

Besides the CA and EA another statutory body which plays a part in the remediation process is the Mineral Planning Authority who are required to grant planning consent for proposed remediation schemes. It cannot be assumed that permission will automatically be granted for any one preferred site since local parties may have conflicting interests. Sometimes the local residents and land owners are not keen to have remediation plants, particularly those which may involve chemical dosing, nearby. At other locations landowners have asked for unrealistic prices for land. Generally, however, all parties have been found to work well together to achieve a successful reduction in polluted waters. The most critical factor during the feasibility phase is often found to be land acquisition and in this respect the CA are “at the mercy of” local land owners. Schemes which have progressed rapidly have often been those associated with land owned by local or county councils, and these are often by derelict or poorly restored industrial areas. The CA does not have compulsory purchase powers available to it at present, but these are currently being sought through the Water Bill which is now being drafted.

Some schemes have been developed with the CA only as a partner. For example at Ynysarwed in South Wales the local authority, Neath Port Talbot CBC, takes the lead role; and at Bullhouse in South Yorkshire, there is a consortium of partners comprising the CA, EA, Barnsley MBC and Hepworth Building Products.

Although the EA is involved in the prioritisation of sites, the CA still need to seek various consents from the EA in respect of proposed schemes. These may comprise some or all of the following: Discharge Consent, Land Drainage Consent, Flood Prevention, Pollution Control, Abstraction Licence, Impoundment Licence.

Currently the CA and EA are having discussions at a national level to try to agree guidelines which could be implemented throughout all regions of the UK.

Table 1

Remediation schemes completed by the CA at March 2000

Site name	Location	Flow [l/s]	pH	Influent tot. iron [mg/l]	Purpose	Water transfer	Treatment system
Woolley	Yorkshire	100	7.0	100	Preventative	Pumped	Passive
Gwynfi	South Wales	10	6.5	7	Remedial	Gravity	Passive
Monktonhall	Midlothian	75	7.0	50	Preventative	Pumped	Lime dose/passive
Minto	Fife	60	6.8	18	Remedial	Gravity	Passive
Polkemmet	West Lothian	60	6.9	50	Preventative	Pumped	Chemical dose/passive
Bullhouse	South Yorkshire	30	5.0	60	Remedial	Pumped	Passive
Old Meadows	Lancashire	43	6.0	37	Remedial	Pumped	Chemical dose/passive
Edmondsley	Durham	5	6.5	20	Remedial	Pumped	Passive
Ynysarwed	South Wales	36	6.0	180	Remedial	Gravity	Active

At March 2000 the CA quoted that a total of 29 km of river had been cleaned up by the mine schemes so far completed (Table 1). They anticipate this to increase to 35 km by the time current construction schemes are completed. Over 40 sites have been the subject of CA feasibility studies, and approximately six new studies and four new constructions are the current annual targets.

SRK's involvement in UK minewater remediation started in South Wales close to the company's headquarters in Cardiff. Scoping (prefeasibility) studies were carried out on behalf of the National Rivers Authority at 17 abandoned coal mine sites. Further work was carried out on behalf of the NRA (Welsh Region) in support of a prosecution against the CA at Ynysarwed with regard to the pollution of 12 km of canal with major fish kills, and an impact on a significant licensed abstraction.

In 1995 the author carried out field visits and mining/geological evaluations for numerous scoping studies in the North of England and Scotland, part of a CA commission to complete studies on the most highly prioritised sites across England and Scotland.

Over the past four years SRK have been successful in the CA's competitive tendering procedure, winning four design and construction contracts (Fig. 1). The first of these at Polkemmet in central Scotland was the outbreak prediction, design and implementation of a contingency scheme to treat rising minewater at a relatively recently abandoned colliery. The other three are located at Edmondsley in County Durham, Fender in Chesterfield, Derbyshire, and at Blaenavon in South Wales. Edmondsley is now fully operational, Fender is in a one year maintenance phase following recent construction; and construction is just commencing at Blaenavon. All three are historical gravity discharges and involve the treatment of net alkaline waters through reedbed cells alone. Two required the pumping of water over a considerable distance to the treatment site. The commissions involved feasibility studies, land acquisition, site investigations, obtaining planning permission from councils and consents from the EA, detailed design, competitive tendering, construction and maintenance supervision.

Fig. 1. Location plan

BRIEF CASE HISTORY OF SITES

Edmondsley (County Durham)

Prior to the recent remediation works a gravity discharge of ochreous minewater emanated from a water level associated with the old East Edmondsley Colliery which was abandoned in 1929. Both shallow drift and deeper shaft workings, to a depth of 220 metres, were interconnected to the water level which lay within the Middle Coal Measures. Overlying strata comprised a thin layer of glacial till and made ground, comprising principally colliery shale, in the vicinity of the reedbed treatment area.

Mine plans, flow measurements in relation to rainfall records, and geochemistry and water temperature research suggest that the discharge reflects an element of both deeper, permanently flooded workings and shallow partially flooded workings which are rapidly recharged following heavy rainfall. This theory seems to be borne out by continuous pumping records kept since the remediation scheme was completed.

The most obvious effect of the minewater discharge had been the accumulation over tens of years of a covering of orange ochre on the bed of the receiving watercourse for a distance of at least 0.5 km downstream. The discharge is net alkaline with total levels of iron and manganese at 20 mg/l and 2.6 mg/l respectively. Flows are generally of the order 5 l/s, but have been recorded up to 13 l/s. Treatment has reduced the outflow levels of iron (Fig. 2) to less than 1 mg/l and manganese (Fig. 3) to a little over 1 mg/l and within two months of the completion of reed planting all the ochre in the receiving watercourse had been remobilised and the rocky streambed left clear.

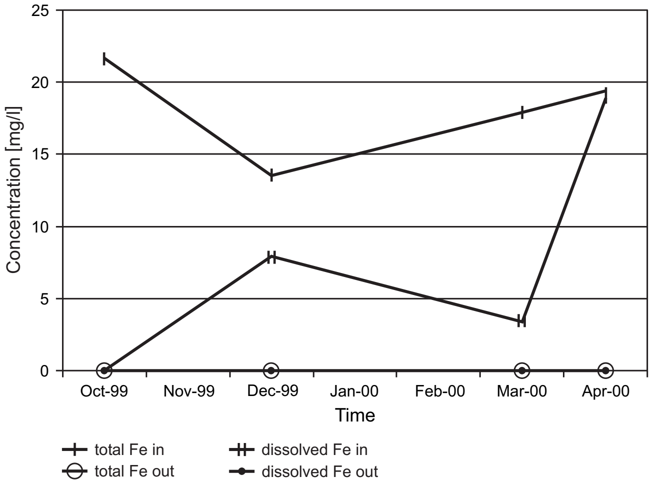

Fig. 2. Edmondsley Minewater, iron content

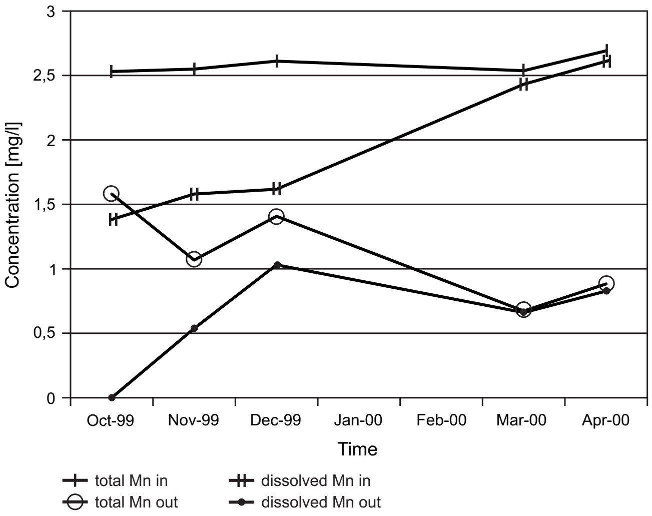

Fig. 3. Edmondsley Minewater, manganese content

Principal elements of the construction scheme comprised:

- cutting back through wooded bank to brick built drainage adit and removing build up of ochre on bank; resealing of adit and insertion of pipe;
- construction of nearby pump sump with two pumps each capable of moving maximum recorded water flow;
- installation of 100 mm pipework through a woodland nature reserve to the reedbed site;
- dial out alarm and water flow monitoring with remote access from SRK office;
- 0.40 ha reedbed comprising three cells, planted with Typha and Scirpus reeds; topsoil growing medium with artificial liner.
- perforated concrete cell dividing walls and stone gabion inflow wall;
- amenity pond, footpaths tree planting, benches, wildflower meadow to encourage public access;
- outfall plunge pool and small waterfall.

Fender (Chesterfield, Derbyshire)

A gravity discharge flowed from pipework directly into an adjacent watercourse, the Barlow Brook. It was found that the pipework had been connected to several capped shafts of the old Dunston Colliery which, following reclamation and redevelopment some 20 years ago, now lie beneath a concreted yard belonging to an adjacent factory. The Dunston shafts are at the lowest elevation of a group of interconnected collieries which were abandoned at around the turn of the 19th century, and lie considerably downdip of the outcrop of the pavement seam which has been extensively worked. Most of the workings are permanently flooded and thus the discharge responds to regional ground water differences rather than individual rainfall events.

The water is strongly net alkaline with a pH of 6.2–7.0; total iron of 10 mg/l; and manganese of a little over 1 mg/l. Ochre staining of the Barlow Brook is strong and the watercourse is affected by the minewater over a distance of some 0.8 km, at which point it reaches a confluence with a larger river. Minewater flows are of the order of 30 l/s.

Construction of a treatment scheme has recently been completed with the main elements consisting of:

- collection chambers at a small seepage from the bank and the main discharge pipe;
- transfer pipework, protected by stone gabion baskets, along river bank to adjacent premises;
- pump sump chamber with additional bank protection;
- control kiosk with dial out alarm and flow monitoring equipment;

- — pipe bridge crossing of Barlow Brook;
- — 250 mm diameter pipework over 400 m to the only remaining suitable treatment site on opposite bank of river;
- — 0.60 ha reedbed with four irregular cells planted with Typha, Phragmites and Yellow Iris in topsoil medium and on artificial lining;
- — concrete cell dividing walls with penstock weirs;
- — outflow pipe and discharge chamber to river (some 500 m downstream of original inflow point).

Reeds were planted this summer and are thriving well, except in cell 1 where the iron loadings are highest.

Polkemmet (West Lothian, Scotland)

Polkemmet Colliery closed in August 1984 and was maintained on a care and maintenance basis until June 1986 when pumping finally ceased. Rising water levels were monitored by British Coal, who retained ownership of the site, and in 1995 SRK were commissioned by a consortium comprising the Forth River Purification Board (now Scottish Environmental Protection Agency), the Coal Authority, British Coal and The Department of Trade and Industry to assess the likely location, timing, magnitude and quality of the expected minewater discharge, as well as potential impacts on potential opencast reserves and opportunities for mitigation.

The area is one of low lying topography with the main watercourse being the eastward flowing River Almond some 2 km to the north. Polkemmet Colliery lies on westerly dipping Lower Coal Measure strata which in turn lie above the predominantly barren Passage and Upper Limestone Groups and the coal bearing Limestone Coal Group.

Coal seams exploited in the region comprise three groups of seams:

- — Lower Coal Measure seams (Fig. 4) outcrop close to and to the west of the Polkemmet shafts and have been worked underground to varying degrees; potential opencast reserves still remained along seam outcrops;
- — seven seams within the Limestone Coal Group were worked at a number of interconnected collieries, of which Polkemmet was the last to close; the eastern limit of workings was marked by the basal seam (Wilsontown Main) outcrop and in the west the workings continued beneath overlying Lower Coal Measure seams; the two sets of workings were separated by some 270 m of unworked strata and no interconnecting shafts or boreholes were known to exist;
- — the lowest worked seams were the Upper Oil Shale Group, with some workings in the Hurlet Seam lying vertically beneath the Wilsontown Main outcrop (some 300 m above); again no interconnecting shafts or boreholes were known; deeper oil shale workings were similarly unconnected.

Having established that interconnected workings within the Polkemmet system were not themselves connected to overlying and underlying workings, the next phase was to establish the extent of interconnection in the Polkemmet system itself.

Workings on the lowest seam (Fig. 5), the Wilsontown Main, extend over an area approximately 8 × 9 km. Four overlying seams were worked less extensively, the upper three generally only within 2 km of outcrop. The workings could be divided into a series of "ponds" where workings were once independent of each other below the levels of direct or indirect connections, or overflow points. As water levels rose above the overflow points, the ponds became linked and water levels on either side of the connection point become inter-dependent.

The most northerly of three ponds (Riddochill) was connected near to the base seam outcrop with the much larger southerly ponds through a small, fault bounded drift mine (Almond Mine). To the north further workings were likely to be isolated by a major east-west trending igneous dyke and unworked zones adjacent to east-west trending faults.

Following the initial cessation of pumping at Polkemmet in August 1984 water flooded to the pit bottom elevation and was then controlled by emergency pumping until final closure,

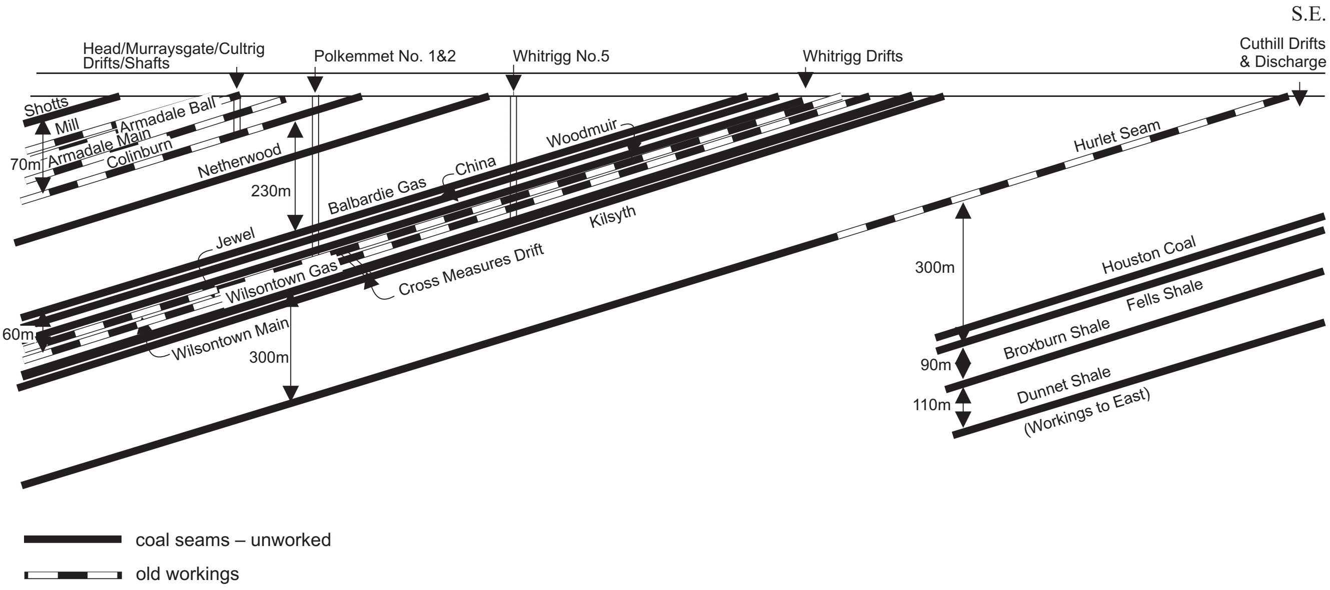

Fig. 4. Schematic cross-section, Polkemmet

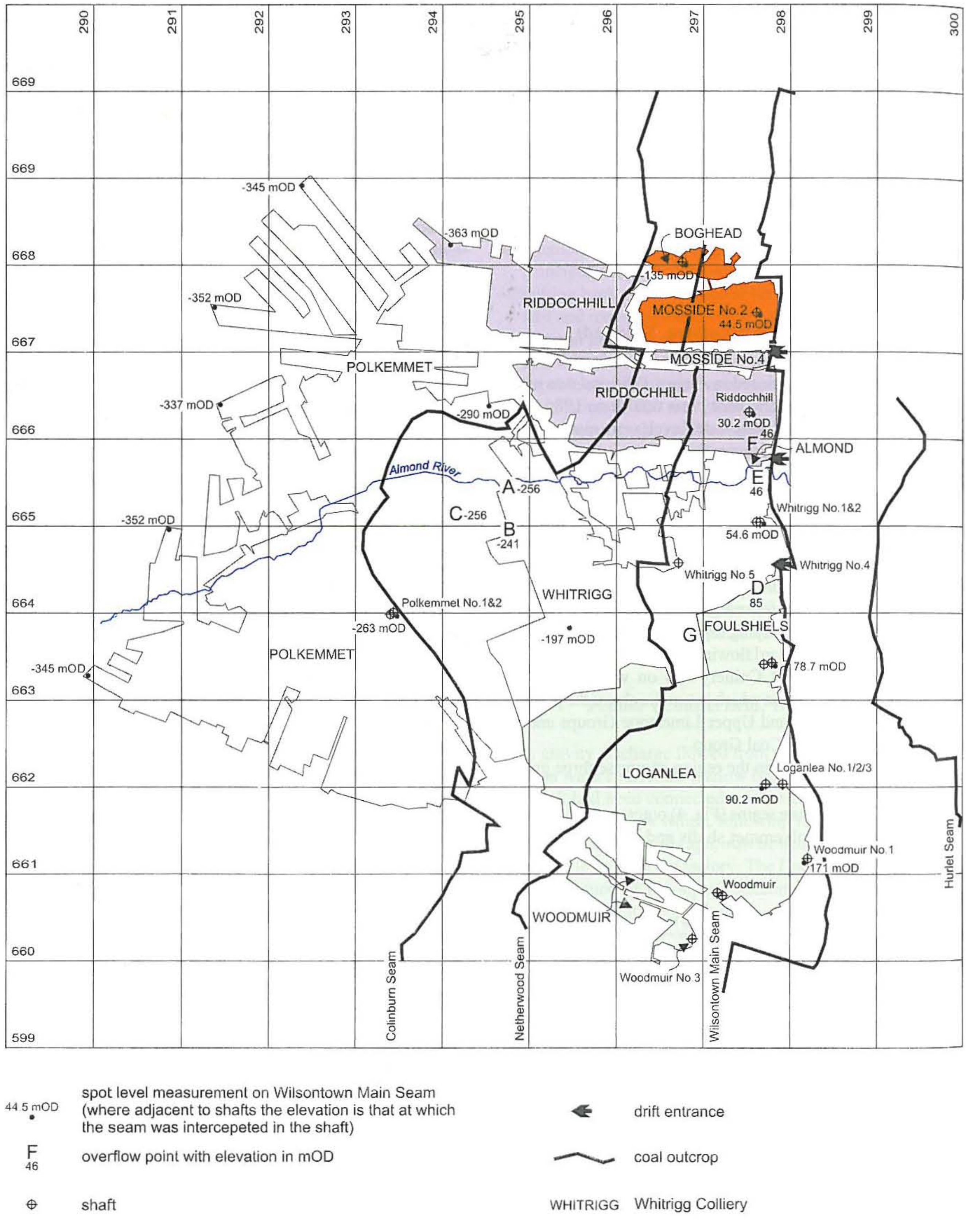

Fig. 5. Composite mine plan, Polkemmet

following independent review, in May 1986. Levels were not then measured until November 1995 when an old shaft cap was opened to facilitate monitoring. Weekly and later monthly measurements were then taken; and at a later date monitoring commenced in a second disused shaft at Riddochill.

Water levels were found to be rising at 0.15–0.20 m per week compared to the historical average rise of 0.80 m per week between 1986 and 1995. The slowdown in recovery was thought likely to be due to the combined result of increasing void space near to the surface (introduction of higher seams and lower seams worked over a wider area) and reduction in driving head for groundwater inflows. Good hydraulic connection between workings was suggested by a low (1:6500) hydraulic gradient between the two monitoring shafts.

Predictions were required to be made regarding outbreak location, outbreak timing, and likely water and flow of discharge.

Because the water levels at the two monitoring shafts were nearly level, it could be assumed that the advancing water front was close to horizontal and therefore, given the flat topography, there was a possibility of discharges at a number of points. The two potential discharge points at lowest elevations and with good hydraulic connection between the workings and the surface were along the base seam (Wilsontown Main) outcrop at the point where it crossed the River Almond (adit to the Almond Mine) and in the vicinity of the adits of Mosside No. 4 Mine. The former was most likely as connection to Mosside No. 4 Mine, to the north was uncertain due to the presence of an intervening fault and a narrow strip of unworked ground. A third, more northerly, location was even less likely due to the presence of a large igneous dyke.

With regards to the timing of the outbreak (Fig. 6), two variations from the then current rate of rise were assumed, that is, a 5% reduction in rise due to reduced groundwater inflow and increased minewater outflow, and summer water level rising at one third of the winter rate. This gave a predicted date of January to August 1998, but with a worst case scenario of December 1996, based on a continuation of water rising at the then current rates.

Summer minimum discharge was calculated as 1.5 Ml/day with a mean winter minimum of 7.5 Ml/day. However the discharge would be likely to be responsive to rainfall with higher flows resulting. Quality of the discharge was thought likely to be near neutral pH, high alkalinity, sulphate in excess of 1000 mg/l, and initial concentrations of iron up to 100 mg/l.

Further monitoring at the two shafts followed, with the additional installation of piezometers at a third location near to the seam outcrop. Following a tense Christmas and New Year in December 1997/January 1998, work commenced on reinstalling pumps at the Polkemmet shaft with chemical, aeration and settlement treatment at the surface. Further modification to the dosing system and the addition of a surface wetland have since followed.

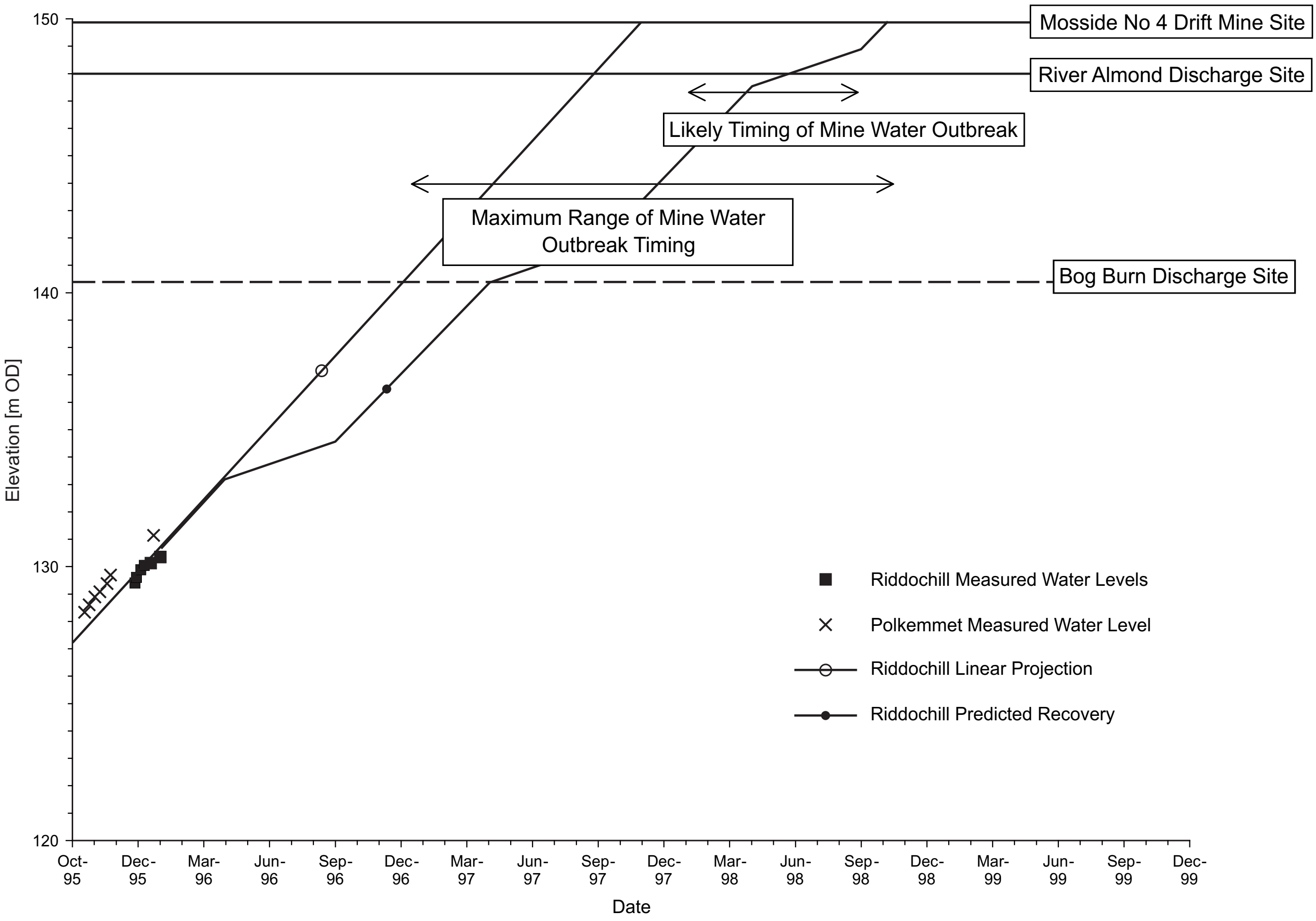

Fig. 6. Polkemmet, outbreak prediction

CONCLUSIONS

SRK's experience of taking several minewater schemes form the desk study stage through to the implementation of remediation schemes has been achieved using a multidiscipline team of coal geologists, hydrogeologists, geochemists, geotechnical engineers, planners, land agents and civil engineers. Some of the lessons learnt to date have been touched upon during examination of the case studies and can be cited as below:

- geochemistry and flow characteristics of historical, gravity flows are easier to categorise than those for preventative outbreaks;
- gravity flows are best treated where the water is already reaching the surface; the consequences of trying to alter the system are difficult to predict with certainty;
- the accumulation of good flow and chemical data over a protracted period will lead to greater design certainty and decreased construction and operating costs;
- schemes often offer opportunities for additional environmental benefits over and above cleaning the existing watercourse;
- some problems, such as ochre removal and disposal, have not yet been encountered at most sites;
- current reedbed sizing criteria are based on US Bureau of Mines guidelines, and tend to be carried out conservatively; further research may reduce over-conservatism and costs; however, it is still better to be conservative at this stage of the learning process;
- treatment of preventative schemes may need to be altered several times before the system "settles down";
- the establishment of various reed species in differing climates, planting mediums and water chemistry should be monitored; quick and effective plant establishment in passive wetlands is crucial to the early success of cleaning water and creating a good impression with the public and statutory bodies; the reed suppliers experience generally lies outside of the treatment of minewater;
- active chemical treatment is more expensive than passive treatment and cannot be as readily "sold" as environmentally friendly;
- innovative designs may lead to considerable capital cost savings.