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The importance of day eyes, level rooms and soughs for mine water drainage

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Abstract

Day eyes, level rooms and soughs are regional names for level tunnels used in early coal mining to drain water from the workings. They exist in most coalfields, with the earliest recorded tunnels dating back to the 16th century. Recovery of mine water levels following the general cessation of coal mining over much of the UK has resulted in re-saturation of the drainage tunnels in many areas. The tunnels, if open, may still act as drains but many have restrictions within the drivages which limit flow and raise water levels in the up dip workings. Raised water levels may result in discharges around the blocked mouths of old tunnels, as at Tunnel Pit, Crooke, or sudden discharges of mine water if blockages away from the mouths fail, as at Sheephouse Wood Adit in Yorkshire. Elsewhere mine water discharges may occur from points well away from the tunnel mouth, as at Swanwick Sough in Derbyshire or Fordell Day Level in Scotland. Therefore, an understanding of the construction and extent of these old mine drainage systems and the risks associated with potential blockages is essential before any construction of a mine water treatment scheme, associated with a sough, is attempted.

Key words: blockages, mine drainage systems, pumping, soughs

THE DEVELOPMENT OF DRAINAGE SOUGHS

The early development of coal mining in the UK was to a large extent governed by the ability to remove water from the workings. Where coal seams outcropped in hillsides and the tunnel to access the coal rose inbye, the water would drain from the workings by gravity. This type of drainage tunnel has existed since Roman times. Elsewhere, coal seams had to be accessed by shafts or dipping tunnels and only small areas of coal could be worked because of the problem of removing water from the workings. In these cases where water could not be drained by gravity it was removed using rag and chain pumps or buckets: the power being supplied by water wheels, steam engines, windmills or horses. These four methods were all commonly in use by the early 18th century. It should be noted that the use of windmills was not considered to be a high-risk option particularly in a country like Scotland where you can normally use wind power for five days in every week. However, the optimum method to develop a 'coal field' was considered to be the use of a level drainage tunnel or sough. This level tunnel driven from a suitable low point at the surface to a position underground in the coal field would allow all the coal up dip to be mined, and any water encountered would drain freely down through the workings, then along the tunnel, and outflow at the surface.

In his Dissertation on Coal in 1740 John Clerk of Eldin describes the use of underground levels to drain large areas of coal as an already well-established method (Figure 1). Guidelines are given in the paper on both the economics and safety aspects of level soughs. For example, the size of the tunnels should be 5½ feet high by 2½ feet wide with air shafts every 50 or 60 fathoms. Air must be forced into the tunnels using bellows, in particular where the levels are deep. By 1740 older levels that had been taken 'a great length by open casts from the surface' were being replaced by deeper levels. New methods of excavating drainage levels using gunpowder had been imported from Germany, and forced ventilation by means of engines had been developed.

The need for pillars of unworked coal to be left to protect soughs and to prevent flows of water from adjacent workings was also well understood by 1740. Pillars of 120 ft were recommended as a minimum size between level rooms that were driven in the coal on strike at an angle to the main level or sough.

Economics of the level drainage was well understood in that the lower the gradient of the level the more coal was accessed. The Bennerley sough in south Nottinghamshire was driven at a gradient of only 1 in 1575 for over 8 km. However, to drive more than 3000 feet

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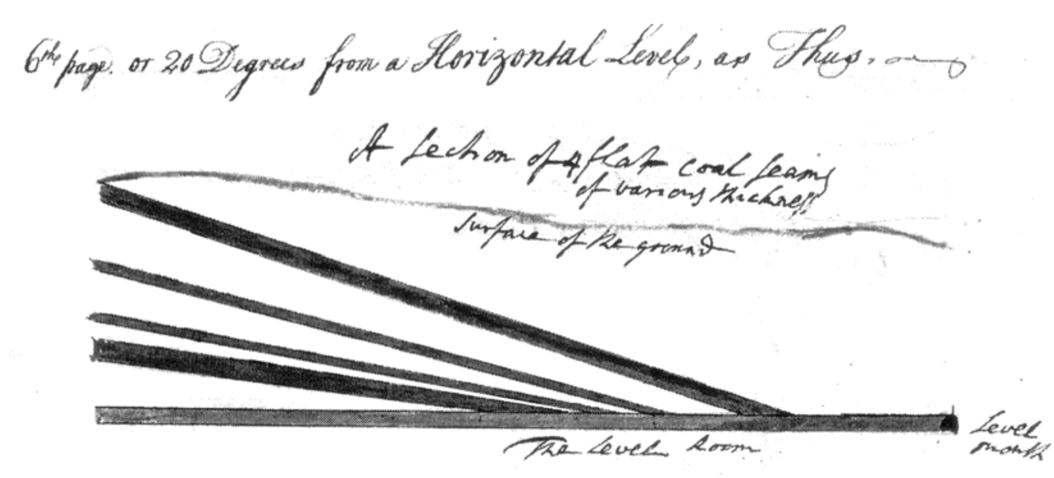

Figure 1. Examples of the use of levels to drain coal. John Clerk 1740

from the level mouth to the contact with the coal was considered uneconomic by Clerk, because of the unknown problems in terms of hard rock and other geological factors that may be encountered. The use of pumping engines driven by steam to dewater mines was still a more expensive option and was only considered where thick extensive coal reserves were discovered that could not be dewatered by level tunnels.

The number of levels or soughs that were constructed to allow the early expansion of the coal mining industry is not known, but they are likely to number in the hundreds if not thousands. In the old NCB No. 5 Area of Yorkshire (South Barnsley) alone there were 56 recorded free drainage adits and there are likely to be many unrecorded. The total discharge of water from those adits in South Barnsley where information was available in the early 1950s was around 75 L/sec (1000 gpm) in winter, reducing to about half this in the summer.

The age of many of the recorded levels is not known, but they would have had to have been constructed over a number of years. The Great Haigh Sough in Lancashire, constructed between 1636 and 1698, only progressed 1121 yards in one period of 17 years. Based on 50 working weeks per year, this is only 1.32 yards per week (Anderson *et al*. 1994).

The drainage of water in the mine soughs or levels and the general expansion of the canal systems in the 17th and 18th centuries led at some point to the combining of the two and the removal of both water and the coal from the mine by means of underground canals. The exact site of the first underground canal system in a coal mine is debatable, but certainly the largest in the UK was the Duke of Bridgewater's canal system at Worsley in Lancashire. This canal system was over 51 miles in total and had canals at four levels capable of carrying boats up to 47 feet long and 4 feet 6 inches

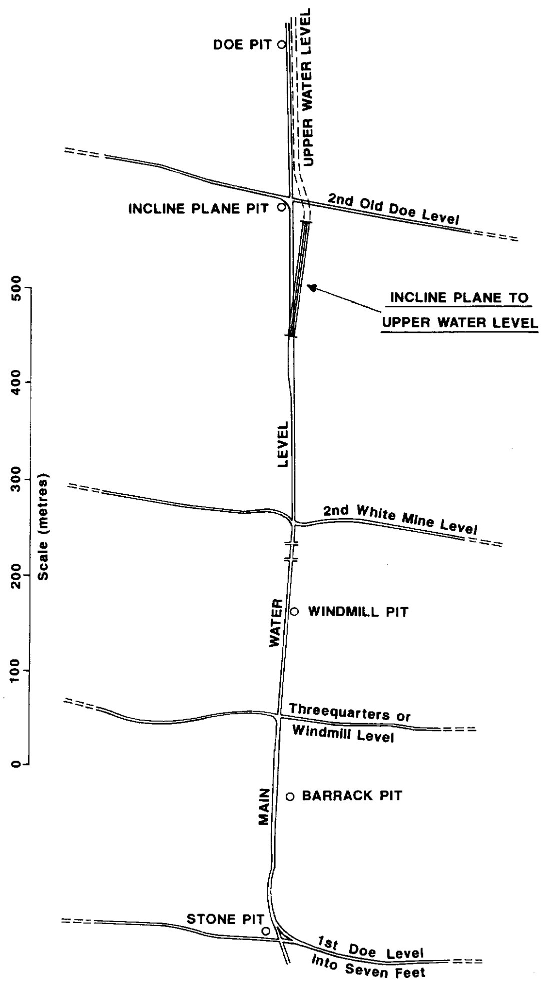

Figure 2. Section of the Bridgewater Canal showing the inclined plane and side canals

wide. Constructed from 1760 onwards to replace several earlier small soughs, the main level at 82 feet above sea level was connected to the upper level between 1795 and 1797 by means of a 1 in 4 inclined plane 151 yards long plus an 18 yard lock (Figure 2). The middle section has a double wagon way to allow the cradles in which the barges sat to pass each other as the weight of the full barge going down raised the empty barge. This was all achieved using hemp ropes and under the gaze of tourists who were taken underground with candles to observe this feat of engineering.

The gradual increase in the depth of coal mining and the use of more modern pumps led to the gradual decline in the use of soughs during the 19th and 20th centuries. Many soughs dried up as mine waters were either drained to lower levels or pumped to prevent possible inrushes to deeper workings. Some soughs continued in use where water was raised from lower levels by pumping and then discharged via the drainage sough but the costs of repairs and lack of access continued the decline in their use. The result was that the former outflow points of many soughs were either intentionally blocked or were simply covered over or forgotten.

IMPLICATIONS OF SOUGHS ON MINE WATER RECOVERY AND DRAINAGE

The existence of an extensive interconnected network of drainage tunnels in mine workings at the lowest level where water would naturally discharge by gravity has become significant with the recent abandonment of coal mining in several coalfield areas.

The mines that were abandoned in the 1980s and 1990s have gradually filled with water to the point where the recovery level is at or above the level of the old drainage soughs. This has resulted in mine water discharge being re-established in those cases where the soughs have remained unblocked. However, in most cases the entrance to the tunnel has become blocked, and water levels may have risen several metres above the old discharge point, resulting in either leakage through the old sough mouth, permeable strata associated with the sough or even boreholes and other man-made connections to the sough. In addition to the problems caused by leakage where a significant head of water builds up against a blockage in a drainage sough, there is also the risk of a sudden failure of the material forming the restriction. This results in a large outflow of contaminated mine water and the material that caused the blockage.

As well as creating potential problems as mine waters recover, the extensive mine water drainage systems can also be seen as a benefit. If water drainage can be re-established either naturally or by man's intervention, then the mine water in a large area of an old shallow mine can be relatively easily controlled at a single point where, if necessary, it can be treated. Therefore, it is important when looking at mine water recovery in an area to establish the pattern of the old gravity drainage systems and their connection, if any, to the deeper modern workings. The mouths of many soughs have remained accessible and there is sometimes a small discharge of mine water from the up-dip areas of mine workings which clearly identifies the source of water.

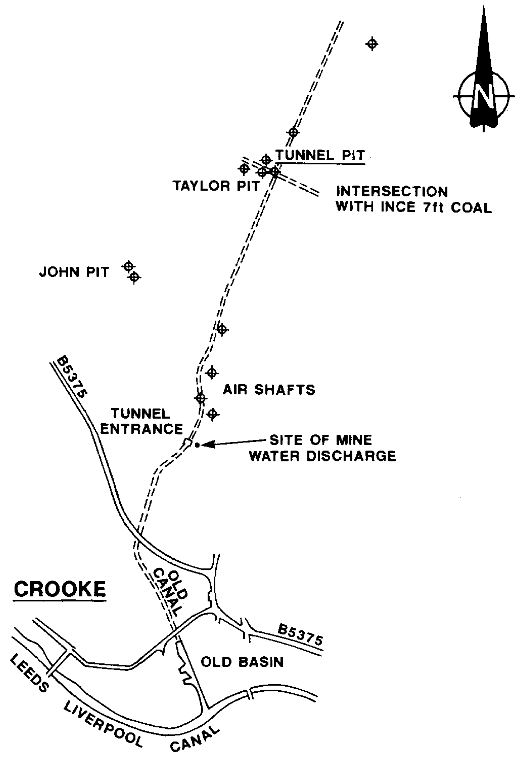

Figure 3. Plan showing the underground canal at Tunnel Pit, Crooke

EXAMPLES OF OLD SOUGHS AND THEIR EFFECTS ON MINE WATER DRAINAGE

IMC Consulting Engineers working on behalf of the Coal Authority are responsible for the historic liabilities associated with coal mining over much of the United Kingdom. Part of this work involves the monitoring of mine water discharges. The Coal Authority is also involved, in conjunction with the Environment Agency, in the control and treatment of these discharges and the prevention of further discharges of polluted mine water. In the course of this work several discharges from old soughs have been investigated by IMC. The details of some of these soughs and the problems associated with them are discussed below.

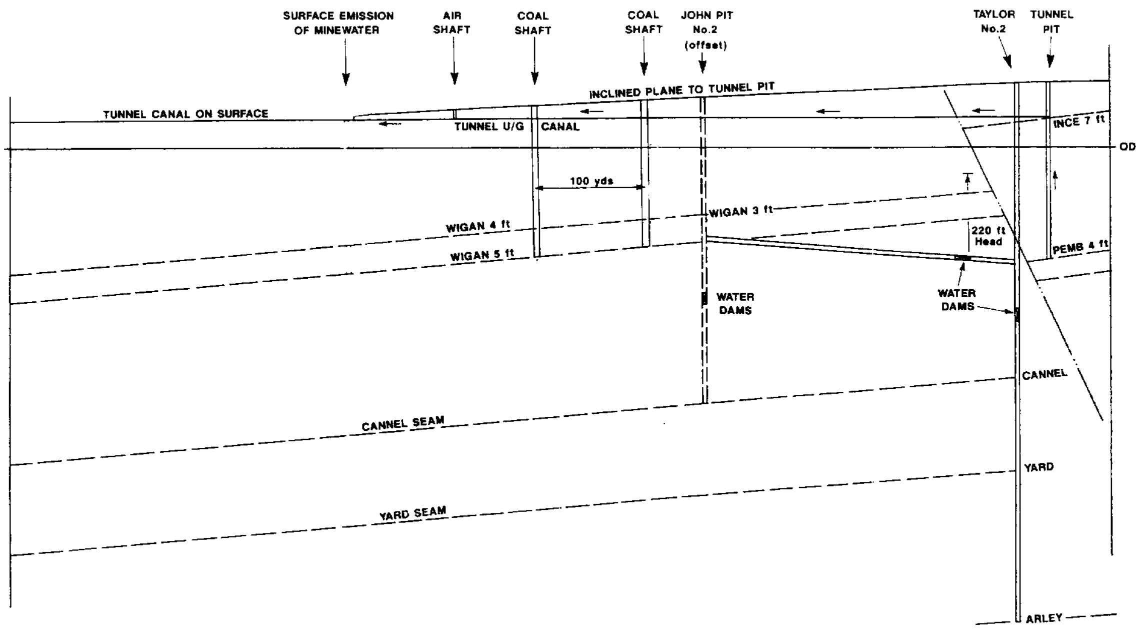

Figure 4. Schematic section through tunnel pit, showing mine water discharge routes

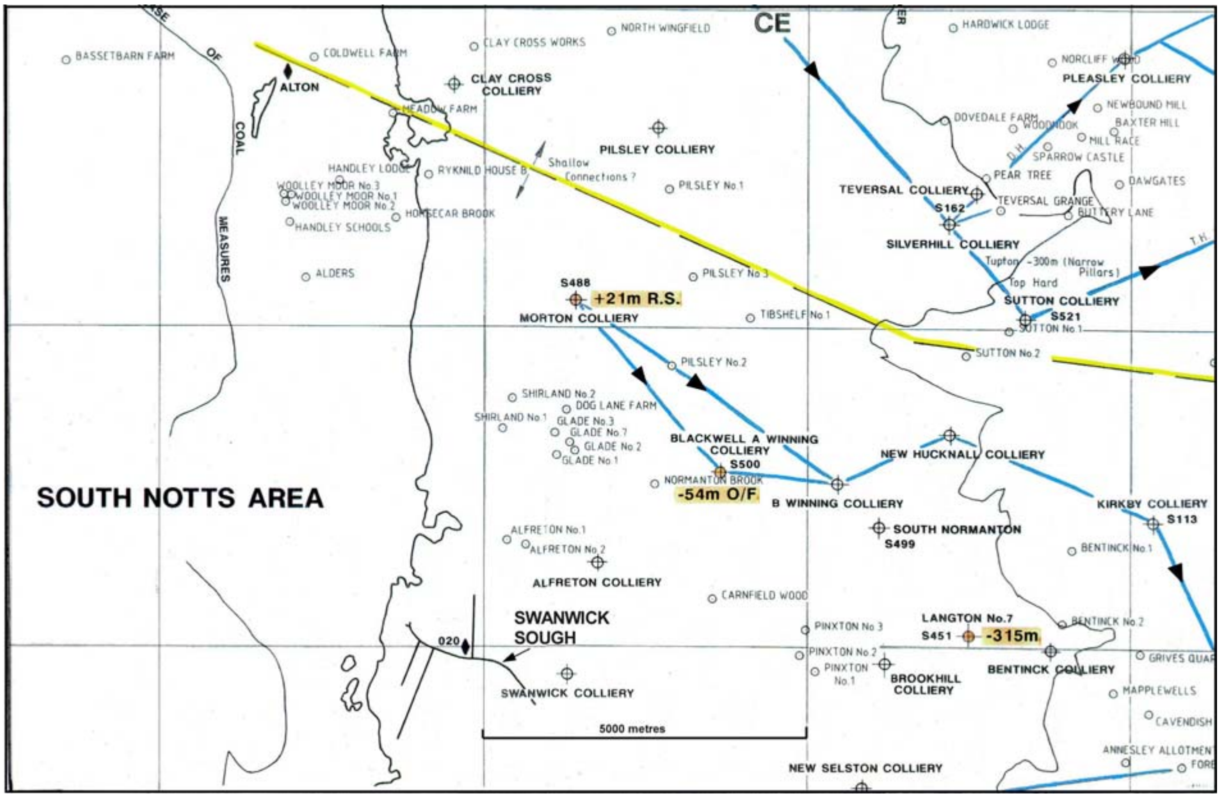

Figure 5. Plan showing the site of Swanwick Sough

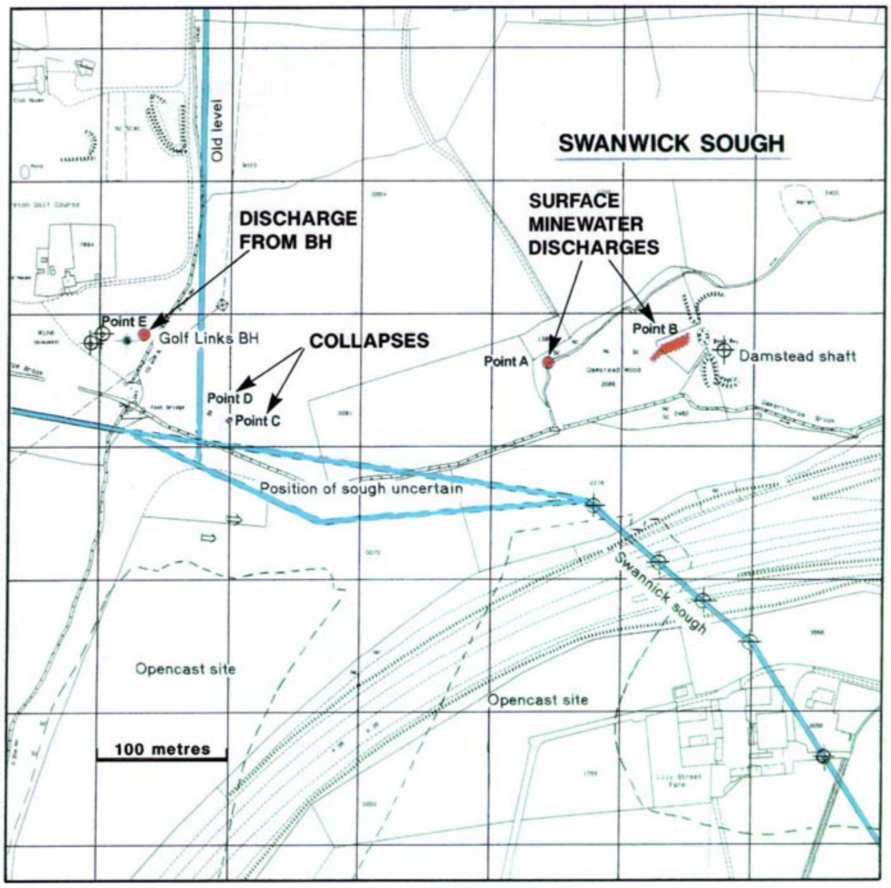

Figure 6. Mine water discharges associated with Swanwick Sough

Tunnel Pit, near Standish, was a mine in South Lancashire that was linked to the Wigan and Liverpool Canal by a branch canal that travelled underground for approximately 1100 yards: halfway along intercepting the Ince Seven Feet (Figure 3).

The underground canal was 9 ft wide and could take barges up to 7 ft wide. It would appear from old surface plans that, in addition to water made from the mine workings, a small surface stream could be diverted underground via a shaft near the inbye end of the tunnel to provide additional water when required.

Tunnel Colliery was closed in the late 19th century and was replaced by deeper shafts known as Taylor Pit which became combined with John Pit (see Figure 4). Following closure of these mines in 1961, water dams were constructed to prevent mine water discharge. The dams were well constructed and a pressure of 95 psi (220 ft) was recorded at John Pit against the dam in the main connecting roadway. Subsequently, virtually all trace of the canal portal or the above surface canal became hidden, buried under colliery spoil which had been spread over the area.

In the 1990s an ochreous water discharge was noted from the fill material close to the former mouth of the tunnel and from the colliery spoil some 50 yards inbye of the tunnel mouth. However, the ochreous water was not the result of surface drainage through the surface spoil, but the result of mine water recovery. Boreholes drilled into the canal tunnel inbye of the collapse area showed a head of water in the mine workings at least 5 m above the surface. Examination of abandonment plans for Tunnel, Taylor and John pits showed that connections in the Pemberton 4 ft coal between Taylor and Tunnel pits effectively by-passed the dams constructed in Taylor and John pits. This meant that as the workings flooded water levels in the extensive up dip workings became higher than the old canal and a positive head of water developed against the material blocking the tunnel exit. The result of this pressure was the leakage of contaminated mine water and the risk of a large flush of contaminated mine water should the colliery waste blocking the exit become saturated and flow.

To reduce the head that had built up in the workings and provide a permanent gravity discharge three, eight inch diameter boreholes were drilled into the open section of the canal tunnel inbye of the blockage. The water collected in manholes then discharged into the natural reed beds that had developed in the marshy ground, resulting from the small initial discharge and surface run-off. This lowered the piezometric head in the workings and has provided a simple long term solution to the problem of mine water control in this area.

Swanwick sough is situated to the south west of Alfreton in the north Derbyshire coalfield and is over 2.5 km long (Figure 5). It also has a number of lateral levels recorded in the various coals that are intercepted. The mouth of the sough is not visible, having presumably been backfilled or collapsed and overgrown. However, the remnants of what appears to be small locks or weirs to control the mine water flow or prevent water from the surface stream entering the sough are still visible. The line of the sough is parallel to the valley of Oakerthorpe Brook into which it discharges. This means that the sough is for a considerable length at very shallow depth relative to the bottom of the valley. The reason for driving such a long level tunnel, when the mine waters could have been drained by a much shorter tunnel only a few metres above, is uncertain. It is possible that it was an economic decision to maximise the coal reserves available or it could have been an environmental decision not to pollute the brook further up stream.

The mine water discharges include a mine water 'fountain' caused by water flow up an unsealed coal exploration borehole. The two collapses shown on the plan are almost certainly related to the main and/or lateral level. The old plans show the soughs and levels as straight lines. However, the old soughs and levels would only remain straight while 'day' light could be used as a guide. Most soughs reportedly wandered and if driven in coal would follow the strike of the coal. Small offsets in the line of soughs or levels reflect a fault displacement. The sough would be driven through the fault and then turn into full dip until it contacted another coal, which it would then follow on strike again.

Sheephouse Wood adit

Not all drainage soughs date back to the 18th century or before. Sheephouse Wood adit in Yorkshire was used to drain water from workings that were only abandoned in the 20th century, the last being in 1963. The adit rose at 1 in 320 and intersected the Hand Bank Colliery Halifax Hard workings inbye of unrecorded outcrop workings (Figure 7). However, Sheephouse adit is not a true sough or level, in that it requires the workings in the Halifax Hard to flood before a discharge occurs. The only workings naturally drained are the very old workings up dip. Hand Bank Colliery was connected by a single roadway to mine workings from School Wells drift. For a number of years water had been flowing from the adit at less than 10 L/sec (130 gpm) and it was naturally assumed that this was the outflow that reflected inflow. However, on Tuesday 26 February this year a mine water discharge occurred that peaked

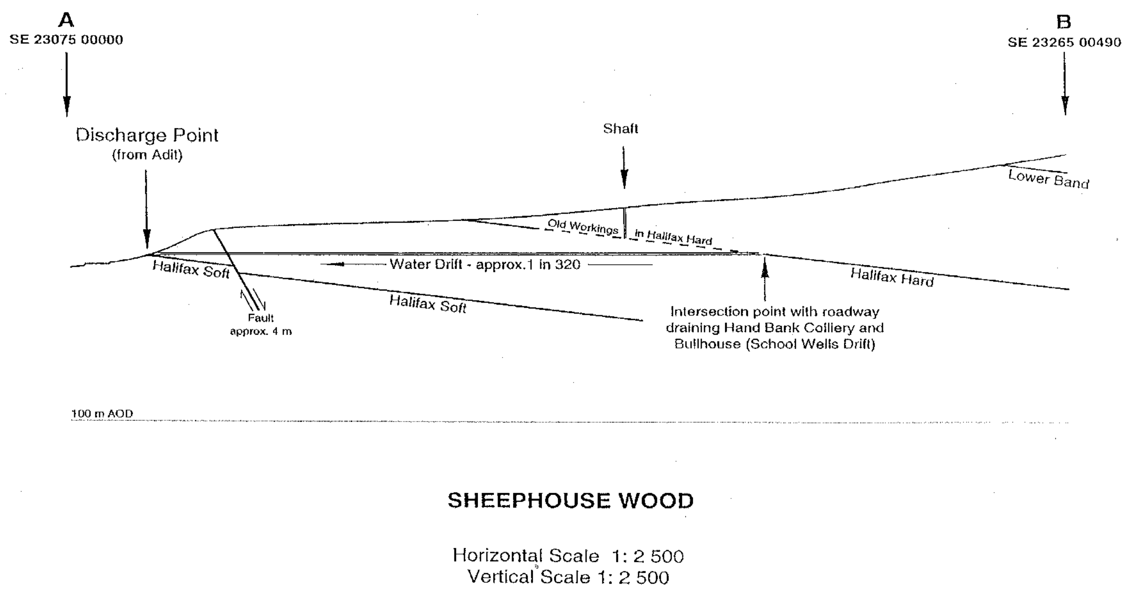

Figure 7. Section through Sheephouse Wood adit

Table 1. Comparison of 1828 analysis of water at Fordell fountain with Fordell Day level

Parameter	Day level discharge			New discharge	Fountain
All mg/L except pH	1985–1995 Average	1990–2000 Average	2001–2002 Average	2002 Average	1828
pH	6.4	6.5	6.4	6.3	
Conductivity		1990	1900	1570	
Iron as Fe	16	13.6	14	>5	5.3
Manganese	5.9				
Alkalinity as $CaCO_3$	270		318		152
Sulphate as SO_4	1200				14
TDS (Calc)					280

at approximately 150 L/sec (2000 gpm), which has since reduced to about 12 L/sec (150 gpm).

The sudden outflow showed that the previous discharge rate was not equivalent to the recharge into the mine workings and that a head of water had been building up over a period of time. The cause and the site of the blockage are not precisely known, but it probably occurred in either the adit itself or the connecting roadway between Bank Colliery and the School Wells Drift workings. It is clear from this example that a flow of water from old mine workings is not a guarantee of free drainage, and, where high piezometric heads could develop in mine workings, water level monitoring is required to warn of potential problems. However, raised water levels in a day level do not necessarily result in a flush of water, this will depend very much on the site of any restriction in flow and the availability of alternative flow paths.

Fordell Day level

This day level is of particular interest, as it is on the Environment Agency and Coal Authority's list of most polluting mine water discharges.

The present flow rate is between 40 L/sec and 50 L/sec (530 gpm to 660 gpm) with a pH of around 6.5 and a total iron of around 15 mg/L. The main level extends

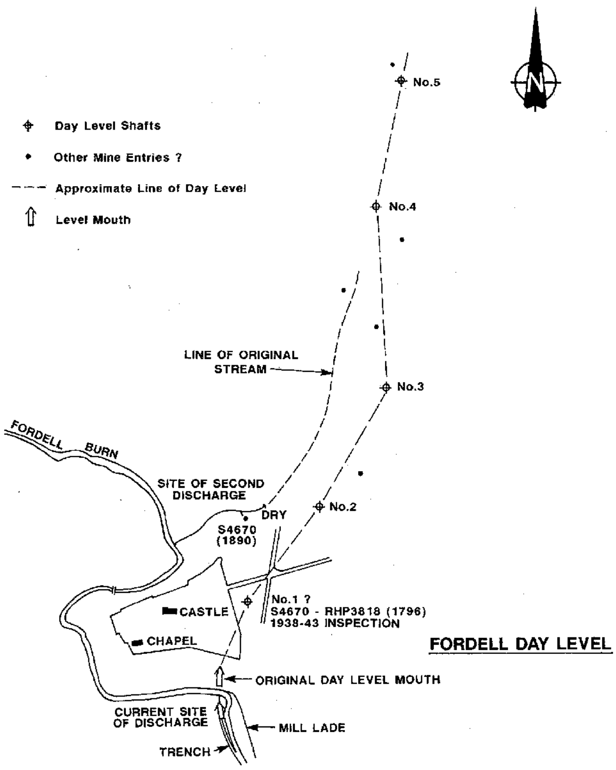

Figure 8. Plan showing the site of Fordell Day level mouth and secondary discharge

inland for about 6 km, and there are several lateral levels at the seam intersections. The area of abandoned workings drained by the Fordell Day level is not precisely known. However, during dewatering at Keirsbeath opencast site to the north west of Crossgates, flows from Fordell fell to as low as 30 L/sec. Historically flows over 200 L/sec were regularly recorded prior to 1985 when the opencast site started.

The start of construction of the Fordell Day level dates back to around 1750, with estate maps dating from 1796 showing the level mouth and shafts along the line of the level. The early plans suggest that the level apparently discharged not into the main Fordell Burn but into a mill lade constructed to carry water to a small reservoir supplying a mill downstream (Figure 8).

At some time the mine water discharge position was changed by driving a tunnel from the old level under Fordell Burn to a new discharge channel on the other bank. This was presumably done to allow polluted mine water to discharge into the burn downstream from where the mill lade was supplied. This was probably only possible because the original mouth of the day level was constructed in dolerite. The strength and low permeability of the dolerite would allow a tunnel to be constructed under the burn without either the water from the burn entering the tunnel or the mine water leaking from the tunnel.

In addition to the main discharge from Fordell Day level, a new discharge has occurred from a site on a small tributary of the Fordell Burn up-stream from the day level and at a level approximately 20 m higher than the main day level discharge. The site of the new second higher level discharge is shown on one old estate plan dated 1790 as a shaft or mine entry and on later Ordnance Survey plans as a chalybeate spring with a pump house adjacent. It would appear that the water from the 'spring' was used for a fountain in the grounds of the estate, and there are records of an analysis of the water in 1828 in the Scottish National Archives (Anon. 1928). The analysis of the water in the fountain appears to have been undertaken because 'it deposits an ochreous substance in its channel'. The fountain could therefore be classified as the first, admittedly inadvertent use of aeration for the precipitation of iron from contaminated mine water. The level of contamination at the fountain is low when compared to the main Fordell discharge, but the water is similar to some of the shafts further up the day level where water levels are higher. Table 1 shows the analysis of the fountain sample converted to milligrams per litre and compared to averages for the main day level and the new discharge (Froggatt 2002).

CONCLUSIONS

Prior to the development of efficient mine water pumps and deeper mining there existed in many of the exposed coalfields an interconnected system of tunnels for the drainage of mine water. The abandonment of coal mining and the cessation of pumping has meant that in many areas water levels are recovering or have recovered to a point where surface discharges are likely to occur. The potential lowest surface discharge sites often coincide with the discharge points for old soughs or day levels which, because they predate the requirement for mine plans, were usually either poorly recorded or unrecorded.

It is important when studying mine water recovery to identify all the potential day levels or soughs in an area, as they may develop as a discharge point for mine water if open, or a potential hazard if blocked. It should also be remembered that, as with all abandoned mine workings, conditions in the numerous tunnels can change. Therefore it is not just sufficient to monitor the water outflow from a sough, there is also a need for monitoring of the mining catchment to establish the stability and the various levels of mine water in the system. Only when the drainage system is clearly understood can expensive mine water treatment schemes be considered either for existing gravity discharges or if necessary boreholes drilled to create a new gravity discharge or for pumping.

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