Environment Agency

Abandoned mines and the water environment

Science project SC030136-41

SEPA Scottish Environment Protection Agency

THE COAL AUTHORITY

Product code: SCHO0508BNZS-E-P

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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Foreword

For the past fourteen years our three organisations have worked together to deal with the one of the more visible pollution legacies of Britain's industrial past. Our mineral wealth put this country at the forefront of the industrial revolution and has given us a rich heritage, but it has also given us a significant, difficult and long lasting pollution problem.

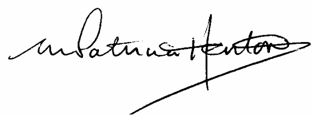
The legacy of coal mining is now well understood. We have a long term programme of work which is dealing with historic discharges in order to improve and protect our inland and coastal waters. We are also monitoring and intercepting water that is still rising in more recently closed mines before it causes pollution or gets into our drinking water supplies. In this report you will see how we have approached the problem, what we have achieved so far, and what remains to be done.

Other mines, particularly metal mines, have not been included in this strategic programme and remain a significant water management issue in many areas. Some of the largest discharges of metals into our rivers and the sea come from abandoned lead, copper and tin mines. Finding a sustainable treatment method for these mines, which does not compromise their value as part of our national heritage and biodiversity, is a continuing challenge.

We are now working to identify which rivers are most affected by these non-coal mines and are looking for ways to manage the pollution.

The valuable knowledge gained from our experience with coal mines will help us to continue working together to solve these problems.

Colin Bayes
Director of Environmental Protection and Improvement
SEPA



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Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Department is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

Steve Killeen

Head of Science

Executive summary

Abandoned mines are one of the most significant pollution threats in Britain. Our legacy of mining for coal, metal ores and other minerals dates back to the Bronze Age. Many thousands of mines have been abandoned and now discharge minewater containing heavy metals and other pollutants into our watercourses. Other more recently closed mines are still filling up with groundwater and will start discharging in the future.

Nine percent of rivers in England and Wales, and two percent in Scotland are at risk of failing to meet their Water Framework Directive targets of good chemical and ecological status because of abandoned mines. These rivers carry some of the biggest discharges of metals such as cadmium, iron, copper and zinc to the seas around Britain. Seventy-two per cent of failures to achieve the cadmium quality standard in freshwater are in mined areas. In some areas, important drinking water supply aquifers are polluted or threatened by plumes of sulphate and chloride.

The legal position in the UK is such that no-one can be held liable for the pollution from the majority of mines. It is only since 1999 that the operator of a mine has had any obligation to deal with the consequences of abandonment.

The Environment Agency, Scottish Environment Protection Agency (SEPA) and Coal Authority are leading efforts to deal with the problem. Between us we have made significant advances, mostly dealing with the problem from coal mines. We have built 54 minewater treatment plants, which prevent 2,500 tonnes of iron and other metals from entering our rivers every year, protecting over 200 km of rivers and drinking water aquifers. Most of these plants are owned and operated by the Coal Authority, which works with the environment agencies to prioritise the worst discharges from closed deep coal mines and identify future problems.

Priority non-coal mines are metal mines in the ore fields of Wales, the South West and northern England which continue to cause pollution despite being closed for over a hundred years. No single body has the responsibility for dealing with them and we do not yet have a national strategy to tackle them.

The Metal Mines Strategy for Wales has identified the most polluting sites in Wales and is working to identify sustainable treatment methods for them. In Cornwall, we have built the largest minewater treatment plant in Britain to deal with pollution from the Wheal Jane tin mine. This plant prevents 670 tonnes of iron and 150 tonnes of zinc from entering the Restronguet Creek each year.

Our strategic approach to identifying and prioritising non-coal mines across England and Wales is set out in a joint project between the Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency. This project, along with a similar assessment carried out in Scotland by SEPA, will identify the water bodies most impacted by abandoned non-coal mines and the sites within them which are the source of pollution. The results of these projects will help to develop a national strategy.

Sustainable technology for treating coal minewater discharges is well developed, but is not directly applicable to most metal mine discharges. Some advances, including pilot-scale treatment plants, have been made but we need to develop passive treatment methods which do not rely on costly technology or substantial raw materials and power.

Abandoned metal mines are not only a source of pollution, they are a part of our national heritage and an important reserve of biodiversity. Many sites are designated as Sites of Special Scientific Interest or Scheduled Ancient Monuments. The tin and copper mining areas of Cornwall and West Devon have been declared a UNESCO

World Heritage Site. This means that certain treatment methods cannot be employed; however, a collaborative approach may help to deal with the pollution threat.

Further work is needed in many areas, including:

- sustainable treatment methods for metal mines;
- a national strategy for cleaning up pollution from abandoned non-coal mines;
- new technologies to recover energy and other resources from minewater and treatment residues;
- monitoring of minewater flow and quality at the catchment scale;
- understanding the impacts of past discharges on sediment quality and ecosystem health;
- developing remedial methods which are sensitive to industrial heritage and other protected sites.

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1 Introduction

Our lives and livelihoods depend on a clean, healthy water environment. We need water to drink, to grow food and to support diverse habitats. Many pressures threaten it and need to be managed to protect and improve the quality of our water. One of those pressures is our legacy of abandoned mines, though many may not have been worked for more than a hundred years.

We have been mining for coal, metal ores and other minerals since the Bronze Age. Lead and copper have been extracted on an industrial scale since the Roman occupation. Mining output peaked in the eighteenth and nineteenth centuries after the industrial revolution, when demand for coal and metal ores was at its highest. As a result, there are many thousands of abandoned coal, metal and other mines but only a handful that are still working.

These sites are one of our biggest sources of water pollution by metals such as cadmium, iron, copper and zinc. Nine percent of rivers in England and Wales and two percent in Scotland are thought to be at risk of pollution from these sites, yet no-one is legally liable for the great majority of them.

We have made significant progress since the last report on the subject (National Rivers Authority, 1994), but there is still a long way to go. This report, by the Environment Agency, the Scottish Environment Protection Agency (SEPA) and the Coal Authority, sets out the nature and scale of the problem in England, Wales and Scotland today, the successes achieved so far and the challenges that remain. This report will feed into future strategies to manage the problem and comply with our responsibilities under national and European law, particularly the Water Framework Directive (WFD).

2 The problem with old mines

We have been mining for coal, metal ores and other minerals in Britain since the Bronze Age, and this has always been accompanied by pollution. Early prospectors relied on this pollution to find metals like silver and tin in streams and sediments. This long history is reflected in place names such as Redruth and the Red River in Cornwall, Afon Goch (red river) on Anglesey and the Ochre Burn in Midlothian. Pollution from mining activities is particularly difficult to deal with because it lasts for a very long time. Thirteenth century coal workings near Dalkeith in Scotland still discharge acidic, iron rich waters into the River Esk (Younger and Adams, 1999).

Water pollution arises from the large-scale land disturbance associated with mining, whether it is opencast, deep mining, or spoil dumping. Many discharges from deep mines can be treated as point sources, but the quality of the water is due to reactions occurring across a large diffuse area that may cover tens of square kilometres. The main sources are the groundwater, which rises after pumping stops, and surface wastes. Figure 2.1 shows the sources and pathways associated with mining pollution.

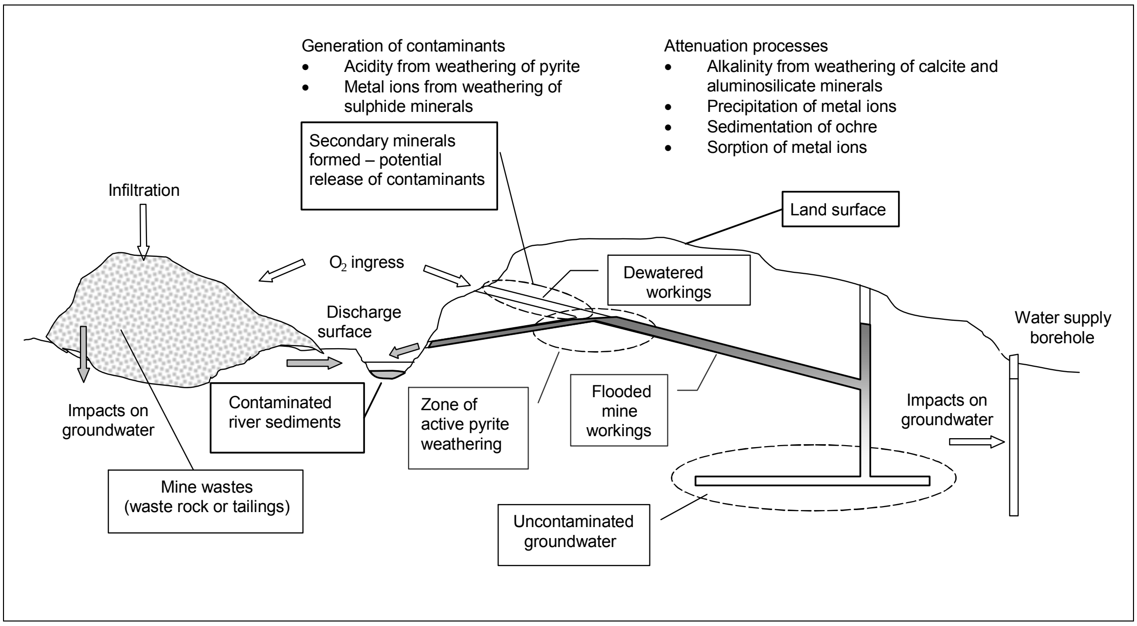

Figure 2.1: Sources and pathways of mine pollution (from Younger *et al.* 2002)

2.1 Minewater chemistry

The chemical reactions that cause minewater pollution start when the mine is working. Water in the mine is controlled by pumping, to keep the mine dry. Sulphide minerals, which are found in coal seams and mineral veins, particularly iron pyrites, are exposed to air and release sulphate and soluble metal ions. When the mines close, the pumps are switched off and the groundwater level rises until it reaches the surface or discharges into overlying aquifers. This may take a few months or many years. Flooding of the exposed seams stops the oxidation of the sulphide minerals, but dissolves the metal ions and sulphates to form sulphuric acid. The effect of this depends on the nature of the rocks. If they contain calcite or other carbonate minerals, the acidic minewater can be neutralised and metals may stay immobile. Commonly, however, the water dissolves any metal compounds present resulting in high concentrations of metals, particularly iron, zinc, copper, lead, cadmium, manganese and aluminium. The quality of minewaters varies considerably; they may be alkaline, acidic, ferruginous, highly saline or clean.

When the rebounding water finally reaches the surface it may come out via old adits, springs, seepage through the ground or even through the bed of a river. When it first emerges it often looks clear, because the underground water is low in oxygen and any metals are dissolved. As the water is aerated in a river, iron rapidly oxidises and settles out as an orange deposit of “ochre”. In some deeper mines, water levels may never reach the surface but may connect with underground aquifers. In these situations, the main pollutants may be sulphate or chloride rather than metals. Minewater salinity increases with depth, and in some cases salt deposits near mine workings can mean that the minewater is more saline than sea water. This is particularly true in the coastal coalfield of North East England. In areas where minewaters have relatively low salinity, this can still be a problem if local watercourses do not have enough flow to dilute contaminants.

Discharges from abandoned mines can vary from seasonal trickles to substantial flows, and are not always polluted. For example, the Meerbrook Sough was built in 1772 to drain lead mines in the Derbyshire Peak District. It now discharges 60 million litres of clean water a day (Shepley, 2007) and is the largest public groundwater supply source in the Midlands. Clean minewater discharges can sometimes dilute the effects of poor water quality in rivers due to industry or agriculture.

Prediction of the time and location of surface emergence is difficult as it depends on many factors. Predictions can be wrong; for example, when the Blaenant colliery closed in South Wales it was expected to discharge from the shaft at the mine site. It eventually came out through much older workings into the adjacent valley at Ynysarwed. The situation can also change, as underground blockages or roof falls can make discharges stop and start again in different locations. This happened at Sheephouse Wood in Yorkshire and at the Pelenna treatment site in Wales.

Predicting minewater chemistry is also difficult as it is the result of many factors which cannot easily be constrained. These factors may differ within the same mine depending on whether they arise from shallow workings and adits or from deeper levels. For coal mines, estimations have been made based on the sulphur content of the coal seams and the proximity of marine bands (Younger, 2000). Very large areas of interconnected collieries, with multiple seams worked at various depths, can lead to large uncertainties in predictions of minewater quality.

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Figure 2.2: Typical ochre deposition downstream of an abandoned coal mine, Aberbaiden Colliery, South Wales

2.2 Diffuse pollution from minewaters

Though the discharges from shafts and adits are often the most visible sources, surface activities such as mineral processing, tailings and waste disposal are also a significant source of pollution. They are often spread over a wide area and many small individual discharges can add up to create a significant diffuse source.

Similar chemical reactions occur in spoil tips so that run-off from them may be acidic, saline and metal rich. The run-off can also carry contaminated sediments, where spoil heaps or tailings are being eroded by rainfall.

The diffuse nature of minewater pollution is best demonstrated by the results from the following recent catchment investigations. These were carried out to establish the relative contribution of diffuse and point sources to the overall water quality in the receiving rivers. For many mine-impacted catchments, remediation of the point sources alone may not improve river water quality sufficiently to achieve the WFD objectives of good ecological and chemical status by 2015.

2.2.1 River Gaunless, County Durham

The River Gaunless is a 93 km^2 former coal mining catchment in County Durham. The environmental quality standard for iron (1 mg/l) is often exceeded in the river. There are six large point source inputs of minewater from former adits and shafts. Newcastle University investigated the flows and water quality in the river and at the point sources over a year in wet and dry weather conditions (Mayes *et al.,* 2008; Younger, 2000). Under low flow conditions, the diffuse sources accounted for about 50 per cent of the loading. Under high flow conditions, this increased to more than 95 per cent. The study confirmed that diffuse inputs from spoil heap run-off, re-suspension of previously deposited iron-rich sediments and direct groundwater input through the river bed are often more important than point source adit discharges.

2.2.2 The Heartlands Redevelopment, Polkemmet Colliery, West Lothian, Scotland

Polkemmet Colliery in West Lothian closed in 1984 and pumping stopped in 1986. Leachate from the large bing on the site has been a significant source of pollution in the Cultrig Burn and the White Burn for many years. Water quality in the White Burn immediately downstream of the bing has been classified by SEPA as poor or seriously polluted since 1999, with iron and aluminium being of particular concern. Following many years as a derelict site, approval was given for the site to be redeveloped. The first stage of the redevelopment is the opencast mining of the remaining reserves beneath the site, scheduled for completion by February 2008. Following extraction of the coal reserves, the bing material will be encapsulated within the backfilled void. Once the site has been restored, it will be used for residential housing, business units, two championship golf courses and a luxury hotel.

2.2.3 Cwm Rheidol, Ceredigion

We have tried to quantify the sources of pollution in a number of catchments impacted by abandoned metal mines to support the *Metal Mine Strategy for Wales*. The Cwm Rheidol complex of six inter-connected lead mines causes the Afon Rheidol to fail environmental standards for zinc and copper, whilst cadmium and lead concentrations are elevated. There are two major adit discharges as well as diffuse discharges from groundwater seepages and spoil heaps. Figure 2.3 shows the proportion of different metal loading from the adits and diffuse sources (Mullinger, 2004). More than a third of zinc, cadmium and copper loadings are from diffuse sources.

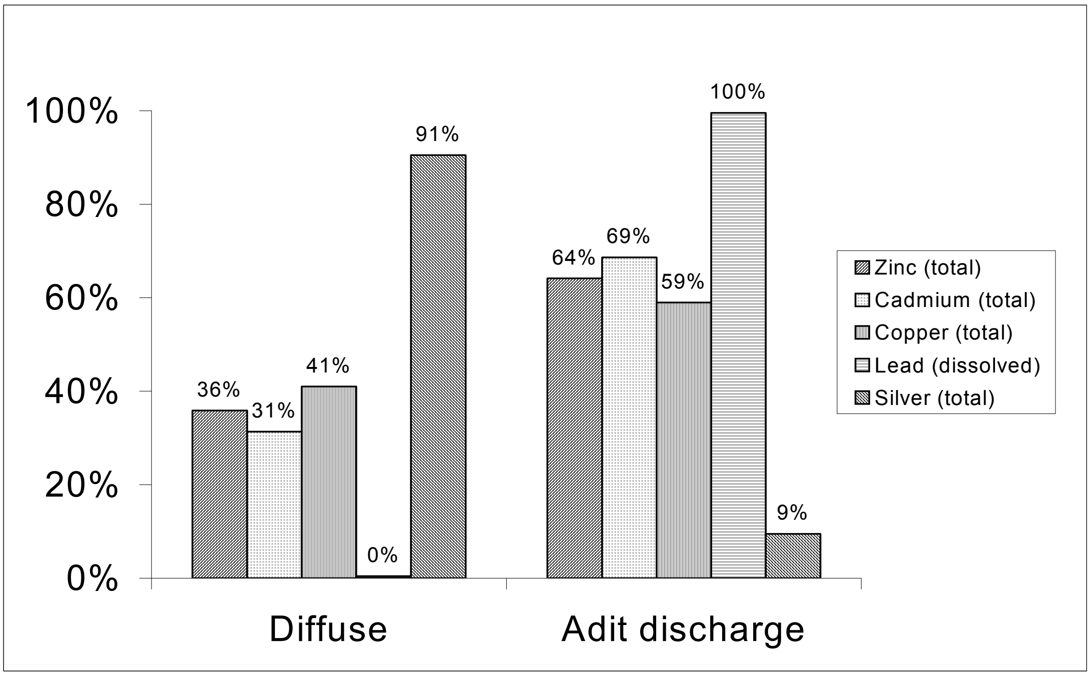

Figure 2.3: Proportions of diffuse and 'point' mine-related pollution around the Cwm Rheidol mine, near Aberystwyth, Wales (after Mullinger, 2004).

2.3 Contamination of soils and sediments

Metal-rich waste materials from mining have severely contaminated river, lake, estuary and floodplain sediments many tens of kilometres downstream of the mines. We have found many significant breaches of sediment quality guidelines for cadmium, lead, copper, zinc and arsenic (Environment Agency, 2008), which indicate that the health of the ecosystem is likely to be damaged.

Floods re-suspend these sediments which can then contaminate floodplains used for agriculture. Metal concentrations in some floodplain soils significantly exceed government guidelines for grazing livestock on former metal mines, particularly for cadmium, lead and zinc (Environment Agency, 2008). The autumn 2000 floods in northern England caused widespread deposition of metals on agricultural floodplain soils (Macklin *et al.*, 2006).

We have estimated that 12,000 km^2 of river catchments in northern England are directly affected by historical metal mining. Over 90 per cent of surface and subsurface floodplain soils have heavy metal concentrations above background levels (Environment Agency, 2008). Similar results are expected for other metal mining catchments in northern England, Cornwall and mid-Wales.

2.4 Ecological impacts

The impacts on aquatic communities may not be immediately obvious, but can have serious environmental consequences. These include:

- reduced numbers and diversity of invertebrates;
- fish mortalities, particularly of sensitive salmonid species;
- loss of spawning gravels for fish reproduction and nursery streams;
- a reduction in numbers and biodiversity in the river corridor.

The ochre deposited by iron-rich minewaters can decimate freshwater ecology by smothering the river bed with iron hydroxides. Natural game fish populations - salmon, sea trout and trout - are particularly susceptible to such pollution as they need open, well-aerated gravels to lay their eggs in.

Low-pH waters can be directly toxic, causing damage to fish gills. Acidic conditions can also increase the solubility and toxicity of metals such as aluminium, copper, lead, zinc and cadmium.

In some areas, particularly upland streams, the natural fish and invertebrate populations are greatly reduced because of minewater pollution. These streams are important as fish-breeding grounds and nursery areas for developing juveniles. The loss of these areas is a major cause of the decline in fish populations which has been demonstrated in some locations. Any changes in the river's ecology can have a knock-on effect on the river corridor as a whole, since riverine birds and mammals such as dippers and otters may be unable to feed sufficiently.

Recovery of ecosystems can be quite rapid when the polluting discharges are treated. For example, a spectacular improvement was observed in the invertebrate population of the Clydach Brook within six months of the Coal Authority implementing a remediation scheme in 2005 (Nesbitt, 2006).

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Figure 2.4: Eroding tailings at a Cornish tin mine

2.5 Economic impacts

Minewater pollution in rivers and groundwater can have a significant economic impact. The aesthetic impact of an iron-rich minewater makes the area less attractive for investment. House prices and job availability can be compromised. The water can be unsuitable for other legitimate uses such as fishing, water sports, irrigation, livestock watering and industrial or potable water supply, all of which have an economic cost. The reduction in the amenity value of an area is recognised by local residents who find the matter of genuine concern. A direct consequence of this visual damage is a reduction in the use of a waterbody for recreational and watersport activities, reducing the economic and social value of the water resource to the local community.

Where pumped minewater was of good quality, a halt in pumping can have other impacts:

- it can affect the dilution of other effluent discharges, resulting in pollution which had not previously occurred nor been anticipated;
- it can reduce the availability of water for abstraction;
- it may adversely influence the amenity value of the watercourse;
- rising minewater levels may cause localised flooding in cellars and low-lying land, and the re-emergence of long dormant springs.

3 Coal mines

3.1 The scale of the problem

We have mined coal in the UK for many hundreds of years. Monks collected coals on the beaches of North East England as long ago as the twelfth century. From these small beginnings, coal and iron became the foundation for the industrial revolution in the eighteenth and nineteenth centuries. At the industry's peak in 1913, a million men worked in 1,600 mines producing almost 300 million tonnes of coal a year. Over 25,000 square kilometres of the country have been affected by coal mining.

As coal mining activities reduced, many mines were closed, underground pumping of water was stopped and the mines began to flood. As the water rose within the underground workings it dissolved metals and other substances, polluting rivers and streams when it reached the surface.

After 45 years as a nationalised industry, in 1994 the remaining coal mines were privatised. The responsibility for managing polluting discharges from abandoned coal mines was passed to the newly formed Coal Authority, which quickly developed a close working relationship with the Environment Agency in England and Wales and SEPA in Scotland, signing formal working agreements with both organisations.

At that time, many hundreds of polluting discharges from mines were affecting many watercourses. Still more were to occur as large areas of mine workings continued to flood. To determine the scale of the problem, the environment agencies and the Coal Authority embarked on a comprehensive exercise to identify the priority sites. The outcome of this work was a list of over 100 polluting discharges spread throughout the coalfield areas of Britain. This list is routinely updated and is still the basis for the Coal Authority's work on treating existing discharges.

Preventing future minewater discharges is the other major element of the Coal Authority's work. The coalfield areas have been divided up into discrete blocks of interconnected mine workings. In each one, minewater levels have been investigated and modelled. Seven hundred monitoring sites record water level and quality across the coalfields. In many blocks, the minewater has already reached the surface and is discharging. Where it has not yet fully recovered, we can use monitoring information to predict if and when it might rise sufficiently to pollute surface watercourses or underground water supplies. Where it is clear that pollution will occur, a treatment facility is built before the water emerges.

Our ability to predict new minewater releases is improving rapidly, but surprises still occur. In 2002, a major outburst of minewater from old workings in South Yorkshire washed away a section of a main trunk road, which had to be closed for several days.

3.2 What we have achieved so far

There are 53 coal minewater treatment plants in the UK. These plants prevent over 1,800 tonnes of iron entering rivers, streams and aquifers every year. The Coal Authority has built 46 of these plants since 1994; 33 treat existing discharges and 13 prevent new uncontrolled discharges. Along with a network of pumping stations, these plants manage over 140,000 cubic metres of minewater every day, and have helped to clean up or protect over 200 kilometres of rivers and streams.

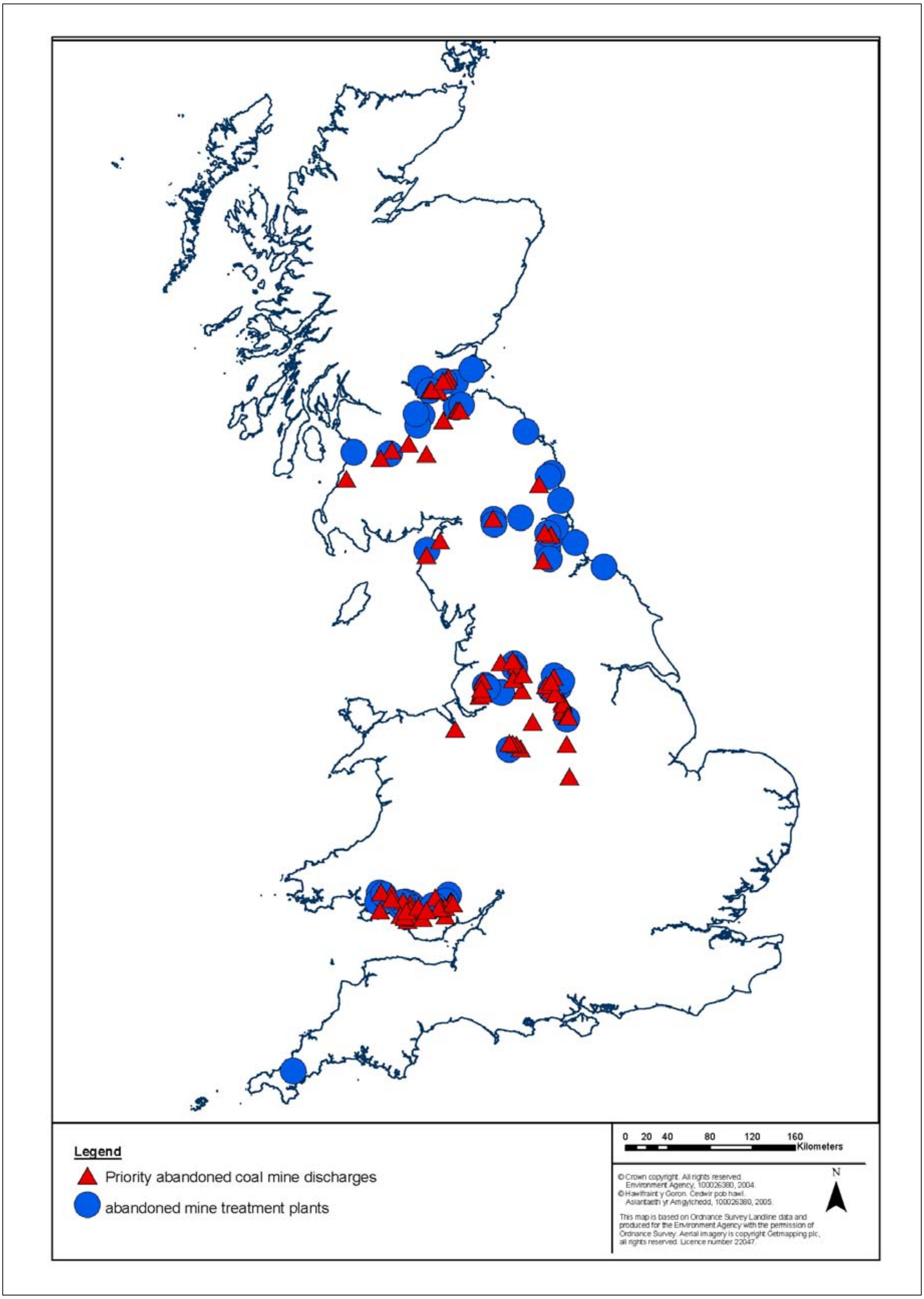

Figure 3.1: Minewater treatment plants and priority coal mine discharges in Britain

The remaining seven treatment plants have been built by other organisations, mainly local authorities. Some of these were built or planned before the Coal Authority was given responsibility for minewater discharges, such as those in the Pelenna wetlands in South Wales. These were built by the Neath Port Talbot County Borough Council in partnership with the Environment Agency, using European Union funding. Others treat discharges from spoil heaps which are not the Coal Authority's responsibility. Examples of these are at Quaking Houses and Bowden Close in County Durham.

Most treatment plants are a combination of aeration, settlement ponds and reed beds. The reeds planted are usually the common reedmace, *Typha Latifolia* and the common reed, *Phragmites Australis*. If there is enough alkalinity naturally present in the minewater the dissolved iron reacts with oxygen, becomes insoluble and is contained in the system, while the clean water is released back into the rivers. The chemical reactions are enhanced by bacteria naturally present in the minewater and wetlands which use iron as an energy source.

These treatment plants have proved to have additional benefits. Wherever possible they are designed to blend into the surrounding area, enhancing the amenity of the area for local people. Public access is encouraged by footpaths and bridges. They also increase biodiversity in the local area by creating new habitats. Wetlands have been in decline in Britain for many years, particularly in industrial areas. Some treatment sites have recorded over 100 species of birds within two years of operation.

At a few sites, the quality of the minewater is not amenable to this method and more innovative methods have been developed. At Pelenna, Tanygarn and Bowden Close Reducing and Alkalinity Producing Systems (RAPS) have been built. This technology uses a bed of compost and limestone to raise the pH and encourage the removal of iron before discharging the minewater through a wetland.

Passive treatment like this is not always possible. Sometimes the quality of the minewater is so poor that treatment with chemicals is the only solution. Usually, an alkaline substance such as lime or sodium hydroxide is added. At some sites, such as Old Meadows in Lancashire, it is added before it enters the otherwise passive treatment system, but at a small number of sites a more industrial chemical treatment method is needed. The fully automated plant at Horden in County Durham, discussed below, is an example of such a site. More detailed information on minewater treatment schemes in the UK can be found in Brown et al 2002.

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Figure 3.2: Minewater treatment in a reed bed

We need a comprehensive groundwater monitoring network to minimise the possibility of environmental harm as minewater levels rise after years of pumping. The number of sites monitoring the status of underground minewater has increased from just over 100 to well in excess of 700. Levels are allowed to rise as high as possible without uncontrolled surface discharges or pollution of clean aquifers, to keep pumping and treatment costs at a minimum; sometimes a gravity discharge can be engineered with no need for pumping. Energy and chemical consumption, and therefore costs, are kept as low as possible to ensure best value for the tax payer and a lower carbon footprint for the remediation programme.

One of the most intensively monitored coalfields in the UK is the East Fife coalfield in Scotland. Minewater levels within this complex are controlled by pumping from the shaft at the former Frances colliery; levels are monitored at shafts and purpose-built boreholes across the coalfield. Over the last few years the Coal Authority, in consultation with SEPA, has allowed levels to rise closer to the surface in order to reduce the pumping requirement. Provided levels across the coalfield can be satisfactorily controlled, this approach will continue to be pursued.

3.3 What is still needed

Despite the success of the minewater programme to date, much has still to be done. The majority of existing discharges on the priority list remain untreated. Underground workings the length and breadth of the country are still filling with contaminated waters, creating conditions for further uncontrolled discharges of minewater. Implementation of the Water Framework Directive (WFD) has provided impetus to the Coal Authority's minewater programme, requiring us to prevent any significant future minewater discharges whilst remediating existing ones that are causing pollution. The WFD has become the single most important legislative driver for the minewater programme**.** Table 3.1 and Figure 4.1 below show how many water bodies are at risk of not achieving good status because of abandoned coal mines (WFD River Basin Characterisation or RBC2).

Table 3.1: WFD water bodies impacted by abandoned coal mines (RBC2)

River Basin District	River water bodies "at risk"	River length km	% of total	Groundwater bodies poor status	Area, km^2	% of total
Scotland	45	436	2	13	4,805	7
Solway Tweed	3	21	<1	2	149	1
Northumbria	36	494	14	5	12,935	83
North West	25	383	8	5	2,905	22
Humber	37	390	4	11	6,531	21
Dee	1	6	1	1	395	13
Western Wales	18	231	6	2	1,302	7
Severn	17	310	4	1	2,358	8
Anglian	0	0	0	0	0	0
Thames	0	0	0	0	0	0
South East	4	18	1	0	0	0
South West	0	0	0	0	0	0
Total	**141**	**2,276**	**4**	**25**	**31,380**	**11**

With so many minewater treatment schemes now working, the amount of iron sludge being removed is growing rapidly. For now it is disposed of to landfill, but considerable efforts are being made to find a beneficial end use for the sludge (see Section 5.2). No solution has been found so far, but it remains high on the Coal Authority's agenda.

3.4 Case studies

3.4.1 Taff Merthyr

When the last of the three collieries in the Taff Bargoed Valley closed in 1993, they left a legacy of minewater pollution and dereliction that had a serious economic impact on the area. Many kilometres of river were blighted by ochre deposition, with a greatly reduced biodiversity. An ambitious regeneration project was planned by Merthyr Tydfil County Borough Council and the local Groundwork Trust to develop the Taff Bargoed Millennium Park. The park was to be a major amenity for local residents and visitors to the area, but would not be able to succeed without a clean river.

The Coal Authority built a three-hectare treatment system with a pumping station, aeration cascades, settlement lagoons and 16 reed beds. The plant now treats up to 120 litres a second, preventing 72 tonnes of iron from entering the river every year.

The commitment to treat the minewater allowed funding for the rest of the park to be released, enabling the project to be completed. The treatment system is now an integral part of the community park, with footpaths and cycle tracks connecting it to the rest of the valley. The large wetlands are a valuable wildlife habitat for many species, and the river is now at the heart of the park and feeds fishing and canoeing lakes. The site is also home to the Welsh National Indoor Climbing Centre, built into the old colliery buildings.

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Figure 3.3: Taff Merthyr minewater treatment plant, the Welsh National Indoor Climbing Centre and riverside park

3.4.2 Mouse Water

The Mouse Water in South Lanarkshire has historically been affected by ferruginous (iron-bearing) minewater from abandoned mines. The very small iron-rich particles (ochre) caused a pronounced turbidity in the main river and, in severe cases, coated the riverbed, smothering invertebrates. This had an effect on fisheries and river ecology in general. Iron levels in the catchment in previous years averaged more than two milligrammes per litre (mg/l). SEPA classified the Mouse Water as poor quality.

A minewater treatment system was opened by the Coal Authority in November 2004, as part of a programme implemented across Scotland. The treatment scheme was constructed on land owned by the Forestry Commission, which was able to influence the design and include it as part of a wider community resource, popular with visitors.

The treatment system is completely passive, with no pumping arrangement required to lift the water to the surface. Minewater with an iron content of 25 mg/l is picked up at source from the existing adit and is channelled to a large settlement lagoon; this lowers the iron to a concentration of less than 10 mg/l. The minewater then enters two large reed beds with a surface area of 8,400 m^2 for further treatment. Finally, the water flows into the Mouse Water with an iron concentration of less than 1 mg/l.

As a result of this work and SEPA's Environmental Improvement Action Plan, a dramatic improvement in water quality over six km of the Mouse Water has been seen, and its status has increased from poor to fair with anticipation of further improvements.

The constructed wetlands protecting the Mouse Water are also a valuable habitat for insects, birds and wildflowers, and with the new footpaths and benches, has become an important amenity within the local community.

Coal Authority

Figure 3.4: The Mouse Water wetlands

3.4.3 Horden

There are situations when it is not possible to use the passive method of treatment used at Taff Merthyr or Mouse Water. At Horden in County Durham, monitoring of groundwater levels indicated that minewater east of the River Wear was recovering to a level where the overlying Magnesian Limestone aquifer was at risk of significant pollution by the iron-rich, highly saline minewater. Twenty per cent of the drinking water in this area came from this aquifer. Monitoring showed that pollution would also arise in the nearby low-lying areas of the Wear Valley and at the coast.

It was clear that a permanent passive solution using reed beds could not be established quickly enough to protect the aquifer. We needed a temporary solution that could be designed and built quickly to occupy a very small surface area. The completed scheme needed to be operational within twelve months to control the rising minewater and prevent pollution of the aquifer.

The solution was to pump groundwater from the colliery shaft into three treatment streams, which separate the iron from the minewater using caustic soda to counter the acidity. Over a tonne of iron is now removed from the pumped minewater every day and the treated water is discharged through a pipeline into the North Sea. Sophisticated control systems give early warning of any problems and the plant is fully automated, constantly monitoring and adjusting its processes to be sure that the water quality being discharged does not cause pollution.

The project was finished within eleven months and now protects the local water supply. A longer term solution for the area will consist of two sites: a large active plant at Dawdon, two miles to the north; and replacement of the active plant at Horden with a more conventional passive solution comprising lagoons and reed beds. This permanent solution will be constructed over three years; construction began in summer 2007.

Coal Authority

Figure 3.5: Horden active treatment plant

4 Non-coal mines

4.1 The scale of the problem

Britain's history of mining for metal ores and other minerals dates back at least 4,000 years to the Bronze Age. The number of mines is vast, but we do not know exactly how many there are. Work in Wales, the South West and Northumbria has identified over 3,700 sites, though not all are causing serious pollution. No metal mines are still in use; the last large tin mine in Cornwall closed in 1998. Deep mines are still working in Sussex, the Peak District, Cheshire and Cleveland for gypsum, salt and potash.

Monitoring has shown that some abandoned metal mines are significant contributors to heavy metal pollution in our rivers and seas. Parys Mountain copper mine on Anglesey is the single largest contributor of copper and zinc to the Irish Sea, discharging 24 tonnes of zinc and 10 tonnes of copper every year (Environment Agency monitoring data: 2003). The Restronguet Creek in Cornwall discharges 52 tonnes of zinc, 12 tonnes of copper and 60 kg of cadmium, which is more than the River Severn. In Wales, the 50 metal mines deemed to be the worst polluters discharge 200 tonnes of zinc, 32 tonnes of copper, 15 tonnes of lead and 600 kg of cadmium annually (Mullinger, 2004). Cadmium is a priority hazardous substance and 72 per cent of failures to achieve its quality standard in freshwater are in metal mining areas, (Environment Agency data: 1999-2004).

The WFD River Basin Characterisation (RBC2) identified which water bodies had a high or moderate risk from mining pollution. Outside of the coal fields, 315 of 7,816 water bodies were found to be at risk, equating to 2,840 km of river. Early results from an ongoing project (Environment Agency SC030136/14) to identify and prioritise non-coal mines using more comprehensive datasets in England and Wales has found that as many as 653 water bodies could be at risk. SEPA is undertaking a parallel process in Scotland, though the problem is thought to be less extensive.

Table 4.1: WFD water bodies impacted by abandoned non-coal mines (RBC2)

River Basin District	River water bodies "at risk"	River length km	% of total	Groundwater bodies: poor status	Area, km^2	% of total
Scotland	2	18	<1	0	0	0
Solway Tweed	3	38	<1	0	0	0
Northumbria	11	212	6	3	3,330	21
North West	12	155	3	1	1,280	10
Humber	8	348	4	1	1,895	6
Dee	9	105	15	1	395	13
Western Wales	87	687	17	6	6,419	32
Severn	31	274	4	1	824	3
Anglian	0	0	0	0	0	0
Thames	0	0	0	0	0	0
South East	1	40	2	0	0	0
South West	153	981	14	6	6,011	15
Total	**315**	**2,858**	**5**	**19**	**20,154**	**7**

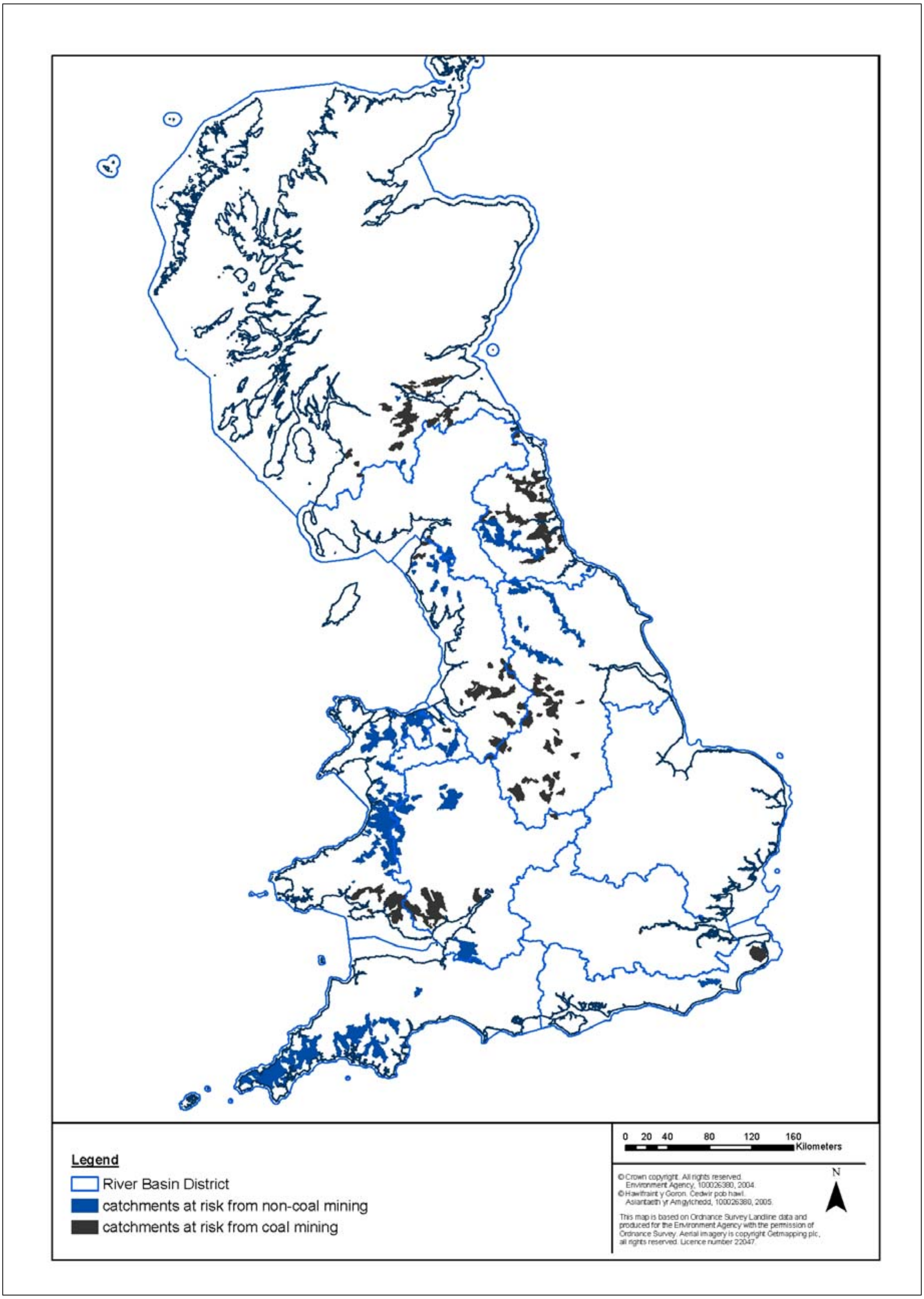

Figure 4.1: River Basin Districts and river catchments at risk from abandoned mine pollution

4.2 What we have achieved so far

Unlike for coal mines, there is no national body charged with dealing with the impacts of metal and mineral mines around the country. There has therefore been no national strategy to tackle the problem. Efforts to deal with the pollution from non-coal mines have been made by us, by local authorities and by regional development agencies in many areas. Most projects have used a civil engineering approach to control leaching and dust generation from spoil heaps, usually because of concerns over human health. In some instances, such as at Bwlch and Cwmsymlog lead mines in mid-Wales, water pollution has not been improved because undisturbed spoil has been exposed to oxygen, causing metals to be more easily dissolved. At other sites, a similar approach has been more successful:

- At Cwmbrwyno lead mine, encapsulation of the fine spoil led to a major reduction in dissolved zinc downstream. (Robinson 2001)
- At Van lead mine near Llanidloes, the concentration of metals was significantly reduced after capping and re-profiling works.
- At Greenside lead/zinc mine in Cumbria, tip stability works to prevent a potential landslide have reduced particulate discharges containing high concentrations of heavy metals in a tributary stream of Ullswater. (Potter et al 2004)
- At Parys Mountain copper mine on Anglesey, an underground dam was removed to prevent a potentially catastrophic discharge of acidic minewater through the town of Amlwch. Minewater now only discharges from one point at the site and a healthy ecology is recovering in an eight-kilometre stretch of the Afon Goch Dulas.
- At the Pumpherston oil shale workings in West Lothian, remediation works have successfully improved the quality of the water environment. Contaminated material is isolated in an underground containment cell and groundwater interception drains direct site water to a reed bed for treatment before discharge to the local watercourse. Part of the site is now a golf course and driving range.

Three non-coal mine sites have been formally determined as contaminated land under Part 2A of the Environment Protection Act 1991. At two, the determinations are for health effects on people taking off-road vehicles or mountain bikes onto tailings dams and spoil heaps, and at the third it is for the harm caused to livestock. None have been determined for the water pollution they cause.

Only one full-scale minewater treatment plant has been built at an abandoned non-coal mine in Britain, at the Wheal Jane tin mine in Cornwall which was abandoned in 1992. Pilot-scale plants to assess the feasibility of treatment by different methods have been built at a few sites in Wales, Cornwall and the North Pennines.

Two Environment Agency regions, South West and Wales have developed detailed databases of the locations of abandoned metal mines. Between them, 3,525 sites have been identified along with summaries of their working history and ore mineralogy. The Welsh database used the information gathered to make an assessment of the risk the site posed to the water environment. It used factors such as available water quality data, the volume of ore excavated and the number of years the site was working to determine risk. In 2002, Environment Agency Wales successfully approached the Welsh Assembly Government for funds to run a strategic project to assess the feasibility of treatment and management options at the 50 most polluting metal mines in their database (Environment Agency Wales, 2002). This strategy has drawn further funding from various sources and has produced feasibility studies for several sites, leading to collaborative projects to construct pilot treatment plants and source reduction measures.

Table 4.2: Pilot treatment plants at abandoned metal mines

Mine	Location	Lead organisations	Treatment type
Bwlch, Esgairhir	Mid-Wales	Aberystwyth University	Dealginated seaweed columns
Cwmrheidol	Mid-Wales	Environment Agency Wales	Reducing and alkalinity producing system (planned 2008)
Nenthead	North Pennines	Newcastle University	Anoxic limestone drains
Parys	Anglesey	Environment Agency Wales, Menter Mon	Chemical alkalinity addition
Scraithole	North Pennines	Newcastle University	Ochre pellet columns
South Crofty	Cornwall	Environment Agency	Anoxic limestone drains and aerobic wetlands
Wheal Jane	Cornwall	Environment Agency	Aerobic/anaerobic wetlands

The Welsh strategy recognised the archaeological and ecological value of many of the metal mines. The sites are an important part of our industrial heritage and many are designated as Scheduled Ancient Monuments. The mines have also developed distinct ecological communities adapted to the physical and chemical character of the sites, with many being Sites of Special Scientific Interest. Local groups were involved in the process and their views helped to divide the sites into four categories, depending on whether our objectives for the sites diverged or converged with theirs. More information on the Wales Metal Mines Strategy can be found on the Environment Agency website.

In England and Wales, the Environment Agency has started a project in collaboration with Defra and Welsh Assembly Government (WAG) to identify and prioritise abandoned non-coal mines causing pollution (Ref: SC030136/14). SEPA is carrying out a parallel process in Scotland. The projects build on the Welsh experience and use a catchment-based approach to identify the water quality problems caused by non-coal mines, from which sources are prioritised using local knowledge. In the first phase of the project, water quality data is used to identify rivers with high concentrations of eight metals commonly discharged from abandoned mines: cadmium, lead, nickel, zinc, copper, iron, manganese and arsenic.

In some River Basin Districts (RBDs), we have good records about the locations of abandoned mines: South West, Western Wales, Dee, parts of Northumbria and Severn. In other RBDs, we used the geology to decide whether mining could have taken place, for example, from the presence of ironstone bands or mineral veins. Using a geographical information system (GIS), we compared the rivers containing high metal concentrations with the locations of abandoned mines or mining geology. This allowed us to make decisions about the likelihood of reported water quality problems being due to mining, and to prioritise the water bodies affected by abandoned non-coal mines.

The next phase of the project will take this information and test it with a questionnaire aimed at Environment Agency and local authority staff with expert local knowledge of the rivers and mine sites. The final outcome of the projects, in 2009, will be a national priority list of the water bodies polluted by abandoned non-coal mines in England, Wales and Scotland and the sources of that pollution.

4.3 What is still needed

A national strategy to deal with pollution from non-coal mines cannot be developed until we understand the scale of the problem. Our work identifying abandoned non-coal mines has started to address this and will produce a national priority list in England and Wales in 2009. To achieve the environmental objectives of the WFD, we must take a catchment view of the non-coal mining areas of Britain and deal with the sources through a Programme of Measures.

Identifying and characterising the problem is only the start. No sustainable, passive or semi-passive method has been established to treat discharges from non-coal mines. The aeration, settlement and wetland approach so successful in our coalfields will not work in areas of acid geology where many of the problem non-coal minewaters lie. Metals such as cadmium, zinc and copper are very soluble in water and difficult to precipitate in the same way as iron, which is the main pollutant associated with coal mines. We have made progress in researching sustainable treatment methods, but there is still some way to go. To achieve this goal, we need a coordinated approach to research and development which will deliver a practical solution.

4.4 Case studies

4.4.1 Wheal Jane tin mine

In January 1992, one of this country's biggest pollution incidents took place when 45 million litres of heavily contaminated water burst from the recently closed tin mine at Wheal Jane in Cornwall. The minewater, loaded with cadmium, arsenic, zinc and iron, flooded into the Carnon River causing a vast plume of polluting orange water in Falmouth Bay.

An emergency treatment plant was built which added lime to the discharge and used the tailings dam at the mine to settle out the worst of the metals. Meanwhile, investigations were carried out to find a long-term solution. A passive solution was investigated first and a pilot-scale treatment plant was built to test combinations of

D Johnston – Environment Agency

Figure 4.2: The Wheal Jane minewater treatment plant

aerobic and anaerobic wetlands. The plant was found to work well but would need so much land to treat the whole discharge that it was not feasible. We decided that an active chemical treatment plant was the only way to deal with the scale of the problem. After tendering, a contract was awarded to a consortium led by United Utilities Plc. to build and operate the plant. The minewater is now pumped from the shaft and lime is added to raise the pH and cause the metals to form insoluble compounds such as oxyhydroxides and carbonates. These settle out with the help of a chemical flocculant and the treated water overflows to the river in compliance with the conditions of a discharge consent set by the Environment Agency to protect the environment. The sludge is pumped into the mine's tailings dam where it is contained.

4.4.2 Cwmrheidol lead mine

The Cwmrheidol lead mine, east of Aberystwyth, is a complex of six mines connected by two deep drainage adits. The mines worked a lead and zinc rich ore body from the eighteenth century until 1914. In its peak year, 1905, it produced 1,537 tonnes of zinc blend (sulphide) and 46 tonnes of lead ore. The two adits now discharge acidic minewater containing high concentrations of lead, zinc and cadmium. The mine contributes half of the metal load in the River Rheidol, which fails to meet its quality targets for 15 km between the mine and the sea.

The Wales Metal Mines Strategy recognised Cwmrheidol as a high priority for action and it was one of the first sites to be the subject of scoping and feasibility studies to investigate what could be done about it. One of the priorities was to reduce the amount of surface water entering the mine, to achieve a permanent reduction in the toxic metal load to the River Rheidol. This was achieved by diverting a stream away from a mineshaft in January 2007. Further engineering works to capture the minewater and reduce erosion of the spoil heaps is planned in 2008.

Environment Agency Wales intends to build a pilot plant to assess the treatability of the minewater using low maintenance and low energy passive methods. Laboratory trials at Newcastle University have helped to shape the design and to identify suitable substrates for the pilot treatment system. Substrates tested include compost, limestone, paper mill pulp waste, ochre from other minewater treatment systems, treated sewage sludge and waste whelk shells from a local shellfish processing plant. Chemical, ecological and flow data has also been gathered to guide decisions about future remediation at this and other sites identified in the Strategy for Wales.

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Figure 4.3: Cwmrheidol lead & zinc Mine, No 9 Adit

5 Future opportunities and considerations

5.1 Treatment methods

The Coal Authority has developed sustainable methods for treating the majority of coal mine discharges, but there is still scope to make these methods more efficient. A novel vertical flow reactor has been developed at Cardiff University which harnesses the properties of iron ochre to create a higher density sludge; the process involved needs a much smaller land area than the traditional aeration and settlement lagoon approach (Sapsford, 2007). At the Lamesley wetland near Gateshead, minewater and sewage effluent are mixed before treatment in a conventional aerobic wetland operated by the Coal Authority and Northumbria Water. The reeds gradually polish the combined flow as it travels through five hectares of wetlands. This facility is unique in the UK and shows the potential for beneficial co-treatment of waste waters from different industries.

A coordinated approach to dealing with coal mine discharges was helped by the CoSTaR project (Coal Mine Sites targeted for Remediation Research). This collaborative project, led by the HERO (Hydrogeochemical Engineering Research and Outreach) Group at Newcastle University, brought together several abandoned mine treatment plants in the North East of England as a research facility to allow technology developments to be shared internationally.

The situation with non-coal mines is less well developed. We can treat discharges with active chemical treatment such as that at Wheal Jane, but the process is expensive and relies on the importing of raw materials and power. Research is ongoing into more sustainable methods at several institutions. Many substrates and techniques have been trialled including de-alginated seaweed, manures, composts, anoxic limestone drains, RAPS systems, coal minewater ochre, and wetlands.

Few of these techniques have been trialled at more than a small scale but they do show promise and we need to encourage larger scale pilot plants like the one built to treat the Red River and South Crofty tin mine discharge at Redruth in Cornwall (Potter & Jarvis, 2006). This plant uses combinations of anoxic limestone drains and aerobic wetlands which encourage the adsorption properties of the ochre in the South Crofty discharge to co-precipitate copper and arsenic present in the Red River from other abandoned mines in the catchment. The project was part of the INTERREG funded Cycleau project which looks at developing sustainable routes to a better environment in Cornwall. Further investigation of this treatment system is being carried out by Newcastle University and the Environment Agency.

5.2 Ochre reuse

The existing coal minewater treatment plants produce about 50,000 tonnes of ochre every year, nearly all of which goes into landfills as a waste. Beneficial uses of the ochre have been researched and include:

- phosphate removal in sewage treatment works;
- a pigment in the dye and paint industry;
- a bulking agent and dye in the cement industry;
- feedstock to the iron and steel manufacturing industry;

- as a substrate for adsorption of other metals in non-coal minewaters.

Though no solution has yet been found, the Coal Authority and the environment agencies are working to identify management options for ochre which promote recovery and re-use of this resource while protecting the environment. Some minewaters contain significant quantities of valuable metals, and the potential for extracting them and other chemicals both from the minewater and from the ochre is an area requiring further research.

5.3 Ecology

Many abandoned mine sites, particularly metal mines, have developed unique communities because of the physical and chemical characteristics of the landscape. Some plants, such as the Cornish Path moss, grow nowhere else. Thus, many sites are designated as Sites of Special Scientific Interest. On the oil-shale bings of West Lothian and the metal mine spoil heaps of England and Wales, locally rare plants and animals are present, including scarce lichens and mosses. This character extends to some rivers where the ecology has adapted to the conditions, with metal-tolerant species or races dominating. Often the acidic conditions mean that species such as snails and other molluscs needing calcium to build shells are absent and the ecology is dominated by other more metal-tolerant species and families, notably certain caddis and dragonfly larvae. Though we may not recognise these communities as a normal healthy ecology, they are very important as part of our national biodiversity and need to be understood and taken account of in any remediation plan.

The long period over which elevated metal concentrations have been present in some metal-mining impacted rivers may have led to fish and ecological communities adapting to high contaminant levels. Further research and monitoring is needed to set appropriate water quality targets in these rivers to support healthy ecosystems. This may lead to metal concentration targets above environmental quality standards.

In a few cases, the pollution is so severe that the ecology is dominated by so-called extremophiles − bacteria and cyanobacteria (blue-green algae) that can tolerate the conditions. These organisms play a significant role not only in increasing the pollution by releasing metals via their metabolism, but in treating the resultant pollution. They are therefore worthy of study to help us develop a sustainable treatment method for abandoned mines.

D Johnston – Environment Agency

Figure 5.1: Parys Mountain copper mine, a site of special scientific interest and a scheduled ancient monument

5.4 Heritage

Because of the important role they played in the development of this country, and in the industrialisation of the world, many abandoned mines are important heritage sites. A great many are protected as Scheduled Ancient Monuments and some, like the tin and copper mining areas of Cornwall and West Devon, have achieved UNESCO World Heritage Site Status.

This importance brings new challenges and opportunities. While protection of the site means that some treatment methods are not suitable, it can be a driver for remediation where the objectives of the conservation bodies converge with those for a clean environment. A good example of this is at Parys Mountain, where remediation activities are led as much by the local industrial heritage trust as by the Environment Agency.

At the National Coal Mining Museum for England, at Caphouse Colliery near Wakefield, rising minewater posed a threat to the underground workings open to visitors as well as to the River Dearne. Working with the Coal Authority, the minewater was controlled by pumping and treated at the surface. The treatment plant is now part of the visitor attraction with hides for bird watching built into the wetlands.

At other important sites, particular risks have been dealt with. At Botallack tin mine in Cornwall, the arsenic condensing flue was cleaned out to allow safe access for visitors.

5.5 Catchment investigations

Detailed monitoring to collect synchronous measurements of minewater and river water quality and flow are needed in priority mining-impacted catchments to identify the key contaminant sources. Our existing routine monitoring network is inadequate for this purpose and so we are unable to design and implement remedial measures to achieve the aims of the WFD.

5.6 Energy and climate change

The impact of climate change could make the problem of abandoned mine pollution worse. Increased storminess and rainfall intensity will increase the erosion of contaminated spoil heap material and sediments, and deposition on agricultural land in downstream floodplains. Prolonged dry spells allow soluble mineral salts to form, which are then rapidly dissolved and discharged in storm events. Increased acidity due to raised atmospheric carbon dioxide levels will increase the solution of minerals. Academic research is being encouraged into the effects of climatic change on pollution from abandoned mines.

Conversely, minewaters can be used as an energy source to offset the use of fossil fuels. Ground source heat pumps can exploit the vast amount of heat capacity available in minewater in abandoned mine workings to provide heating or cooling in buildings. Ground source heat is currently underdeveloped in the UK compared with Europe, and is expected to be a growth area in the near future. Some research in the USA has shown that acidic minewaters can be used in a fuel cell to generate electricity. (Shaoan Cheng et al 2007)

5.7 Contaminated sediments and floodplain soils

We need to investigate whether the elevated concentrations of metals in sediments and floodplain soils are damaging ecosystem health, and if remediation or other management options should be implemented.

6 Legislation and policy

6.1 Water

The Water Resources Act 1991 (WRA 91) is the most important piece of pollution legislation in England and Wales. It outlines the principal offence that a person contravenes the act if he or she:

> "*causes or knowingly permits any poisonous, noxious or polluting matter or any solid waste matter to enter any controlled waters.*"

Until 31 December 1999, Section 89(3) of the same act contained a defence that:

> "*A person shall not be guilty under Section 85 by reason only of his permitting water from an abandoned mine to enter into controlled waters*."

In Scotland, the Control of Pollution Act 1974 (COPA 1974) was the main piece of pollution legislation until 2003 and the offences were identical to WRA 1999.

It is worth noting that the defence was only for "permitting" a discharge; it did not extend to "causing". But because of the complexities of history, underground connections between mines and ownership of abandoned mines, it could not be proven that the act of abandonment was in itself "causing". Rather, it was just one link in a chain of events starting with the opening of the mine, which was rarely done by the same person who closed it.

Because of this, there has only been one successful prosecution for causing pollution from an abandoned mine in Britain and that was taken in 1981 under the Rivers (Prevention of Pollution) (Scotland) Act 1951. This was for a mine which had been operated by the National Coal Board from its opening in 1951 to its abandonment in 1977. For other high profile polluting abandoned mines, including the Wheal Jane tin mine, prosecutions were not taken following legal advice that "causing" could not be proven because of its long and complicated history. In 1993, the Anglers Cooperative tried a test case in Wales to prove that British Coal had caused a discharge from the Britannia Colliery into the River Rhymney. The case was rejected after appeals to the High Court.

This defence was removed from WRA 91 and COPA 1974 for Scotland in 1999 by Sections 58 and 59 of the Environment Act 1995, but only for mines abandoned after that date. Thus, the defence is still valid for any mine abandoned on or before 31 December 1999.

This change in the law was accompanied by new regulations: the Mines (Notice of Abandonment) Regulations 1998 and Mines (Notice of Abandonment) (Scotland) Regulations 1998 which required the operator of a mine to give six months notice to the appropriate agency of the abandonment of any mine or part of a mine. These regulations also introduced a new definition of "abandonment" which included "*the discontinuance of any or all operations for the removal of water from the mine".*

The notice must include a report detailing the water control regime in the mine and an opinion of the consequences of abandonment. The agency is then able to agree management options with the operator to avoid pollution. If such an agreement is not forthcoming, enforcement action may be taken against the operator.

Section 161 of the WRA 91 and section 46 of COPA 1974 give the environment agencies the power to serve notices or to carry out works to remedy or mitigate pollution in controlled waters, and to recover the costs of those works from any person who caused or knowingly permitted the pollution. Like the pollution offences in Section 85, WRA 1991 costs cannot be recovered from a person who permitted the pollution before January 2000. Where no liable person can be found to recover costs, we can apply to Defra, WAG or the Scottish Government for funds.

In Scotland, much of COPA 1974 has been repealed and similar powers are now afforded by the Water Environment and Water Services (Scotland) Act 2003 (WEWS 2003), which gave Scottish ministers powers to introduce regulatory controls over activities in order to protect and improve Scotland's water environment. These regulatory controls are contained in the Water Environment (Controlled Activities) (Scotland) Regulations 2005.

6.1.1 Water Framework Directive

This is the most important piece of European legislation which will affect how we deal with pollution from abandoned mines.

The Water Framework Directive (WFD) will be implemented through River Basin Management Plans. Britain has been divided into twelve River Basin Districts (RBDs), each overseen by a panel of people from diverse backgrounds who have an interest in the quality of the water environment. The RBD will be the strategic level at which decisions are made and about which reports are made to the European Commission. Each RBD is made up of many water bodies which represent the surface water catchments and groundwater units. Each RBD has published a Significant Water Management Issues Report; eight of them have identified abandoned mines as a significant pressure. More information on the Water Framework Directive can be found on the Environment Agency or SEPA websites.

The directive has several overarching aims which are relevant to abandoned mines:

- *No deterioration*. Minewater is still rebounding in many coalfield areas following the cessation of pumping on mine closure. Contaminant-laden groundwaters are likely to cause deterioration of surface water and groundwater quality if they are left to rise unabated.

- *Aim to achieve good ecological and chemical status by 2015*. The status of water bodies is defined by a combination of factors, including chemistry, ecology and fisheries. The unregulated loading of metals from abandoned mines will have a significant impact on the achievement of good chemical and ecological status in surface water bodies, and good chemical status in groundwater. In particular minewaters contain significant concentrations of copper, zinc and iron, metals which will contribute to the assessment of ecological status. There are existing standards for these substances and we must maintain an equivalent level of control to ensure that there is no deterioration.

- *Protected areas*. Pollution associated with abandoned mines may cause protected areas to fail their objectives. Areas include those designated under the Freshwater Fish Directive, Habitats and Birds Directives, Bathing Waters Directive and Shellfish Waters Directive, and Drinking Water Protected Areas designated under the WFD.

- *Progressively reduce pollution from priority substances*. *Cease or phase out discharges, emissions and losses of priority hazardous substances.* Minewaters and discharges from mine spoil heaps can contain cadmium, a priority hazardous substance, and lead and nickel which are priority substances. Many of the failures of existing environmental quality standards for these substances are in mining areas. We must aim to progressively reduce pollution from priority substances and to cease or phase out discharges of priority hazardous substances by 2025.

- *Prevent or limit the input of pollutants to groundwater. Reverse significant and sustained upward trends in pollutants to reduce pollution of groundwater*.
  In certain RBDs, notably Northumbria, the North West and Humber, rising groundwater contaminated by minewater threatens overlying aquifers, including public supply sources. Significant and sustained upward trends in pollutants are being seen in these aquifers and more will occur unless action is taken.

6.2 Land

Part 2A of the Environment Protection Act 1990 defines contaminated land as:

Any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that —

(a) significant harm is being caused or there is a significant possibility of such harm being caused; or

(b) pollution of controlled waters is being, or is likely to be, caused.

The Act requires local authorities to inspect land in their areas and identify sites which meet that definition and to enforce remediation on "appropriate persons". These persons are divided into two classes:

- Class A: the person who caused or knowingly permitted the substance to be in the land.
- Class B: the owner or occupier of the land

The legislation contains a defence which mirrors that in Section 89 of the WRA 91, so the enforcing authority cannot serve a remediation notice on any person who knowingly permitted a discharge from an abandoned mine before December 1999. "Causing" needs the same level of evidence as it would for a pollution offence and as such is impracticable. Action can only be taken against a Class B person if no Class A person can be found, but they have no liability for significant pollutants where the receptor is controlled waters.

Where no appropriate persons can be found, the enforcing authority can undertake remediation and a financial resource is available through Defra, the Scottish Government or Welsh Assembly Government to facilitate this.

Three abandoned mines sites have been formally determined as contaminated land (January 2008), in one case because of the impacts on grazing livestock, and in the other two for potential health risks to people using the sites for off road vehicles.

6.3 Other European legislation

6.3.1 Mining Waste Directive

The Mining Waste Directive will mean a new regulatory regime to control waste facilities at working mines and quarries, but also has implications for abandoned mines. By 2012, member states have to "*ensure that an inventory of closed waste facilities,* *including abandoned waste facilities,… which cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment is drawn up and periodically updated."*

6.3.2 Environmental Liability Directive

The Environmental Liability Directive was adopted on the 21 April 2004 and Member States are expected to comply with the Directive from the 30 April 2007. The Directive's aim is in line with the principle that the "polluter pays" for remedying environmental damage or preventing imminent threats of such damage. There are three types of damage: water damage, land damage and damage to protected species and natural habitats. It only applies to damage caused after the 30 April 2007 and will therefore not apply to mines abandoned before then, but may apply to mining activities after that date.

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Glossary

Abandoned mine	Any underground mine that is no longer worked.
Active treatment	A treatment method which involves regular and routine import of power and raw materials.
Adit	A horizontal tunnel, or level, dug into a mine to provide drainage.
Aquifer	A body of groundwater contained within permeable or porous rocks.
Bing	A Scottish term for a waste rock pile.
Diffuse pollution	Pollution arising from many dispersed sources.
Flocculant	A chemical substance which helps particles in suspension stick together, so helping them to settle out.
Level	A horizontal tunnel to access or drain the mine.
Minewater	The groundwater which runs into a mine during and after it has been worked.
Non-coal mine	A mine worked for any mineral other than coal.
Ochre	The orange deposit of iron compounds which settles out from minewater, usually a combination of iron hydroxides and oxyhydroxides.
Passive treatment	A treatment method which does not require regular and routine import of power and raw materials.
Pollution	The introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems, which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment.
RAPS	Reducing and Alkalinity Producing System: a passive treatment using a bed of limestone and an organic material to add alkalinity to an acidic minewater in a low oxygen environment.
River Basin Characterisation	A Water Framework Directive exercise to identify all water bodies at risk of failing to meet their objectives from various pressures.
Salmonid	A fish of the genus *Salmo*, including Atlantic salmon, brown trout and sea trout.
Sough	A colloquial term for a mine drainage level.
Tailings	The fine waste produced in ore processing.
Tailings dam	A structure built to contain the tailings.
Water body	The smallest management unit used in the Water Framework Directive.
Water Framework Directive	A European Directive to improve and protect the quality of our waters.

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