Prioritisation of abandoned non-coal mine impacts on the environment

SC030136/R13 Hazards and risk management at abandoned non-coal mine sites

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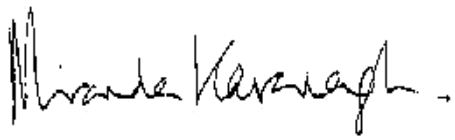

Miranda Kavanagh

Director of Evidence

Executive Summary

The *Prioritisation of abandoned non-coal mine impacts on the environment* project has generated the most definitive evaluation to date of the impacts on the water environment from abandoned non-coal mines across England and Wales. For the first time, an objective assessment has been carried out to prioritise the rivers in England and Wales where pollution from these mines has the highest impact, and where there is the greatest risk that water bodies (river stretches) will fail to meet the objectives of the Water Framework Directive due to abandoned non-coal mines. The specific water bodies which should be the focus of immediate attention in River Basin Management Plans (RBMPs) have been identified, and the work needed to address mining pollution through both research into passive treatment technologies and catchment monitoring investigations is outlined. This Executive Summary details the key outcomes from the entire project, and therefore incorporates elements of the conclusions of all 13 reports that comprise the final deliverables of the project.

Assessing water bodies using water quality, ecological, groundwater and higher impact metrics it has been possible to prioritise *Impacted* and *Probably Impacted* water bodies into ranked lists. The primary focus is the impacts of polluted water discharges from abandoned non-coal mines to surface water courses. Additional information collated in the database also enables assessment of what the other issues are at these sites, such as safety issues, outbreak risk and stakeholder concerns. Taken together this provides a valuable resource to assist in the long-term remediation planning at polluting abandoned non coal mine sites in England and Wales. The absolute scale of environmental problems and risks associated with abandoned non-coal mines is summarised as follows:

Risk	Number
Water bodies *Impacted by* non-coal mine water pollution	226
Water bodies *Probably Impacted by* non-coal mine water pollution	243
Confirmed mine water discharges	257
Suspected mine water discharges	81
Documented evidence of outbreak risk	19
Mine sites at which there is evidence of diffuse non-coal mine water pollution	112
Definite concerns of airborne pollution, stability, safety, and / or public & animal health	425
Suspected concerns of airborne pollution, stability, safety, and / or public & animal health	275

As well as showing the absolute scale of environmental problems associated with abandoned non-coal mines, additional data collated illustrates the specific nature of these problems, and also the areas of England and Wales in which such problems are most acute (reports III – XI report specifically on problems within individual River Basin Districts of England and Wales). The logical next step is to consider how to actually address these issues, and two of the reports arising from this project are dedicated to precisely that (Reports XII and XIII). *Generic* recommendations on how to manage abandoned non-coal mine drainage problems are provided, with *specific* guidance on aspects that have not previously been addressed elsewhere. In light of

the information provided in these reports, the main overall conclusions and recommendations regarding the future management of abandoned non-coal mines can be summarised as follows:

- It is essential to have a clear understanding of the exact sources of pollution if an effective remediation programme is to be instigated. In some instances a single source of non-coal mine water pollution is clearly the main problem, but in the majority of water bodies there are multiple sources. Diffuse sources of mine water pollution are a major contributor to overall metal flux in abandoned non-coal mine catchments. In very few water bodies is there a clear quantitative understanding of how individual sources of pollution from abandoned non-coal mines contribute to the overall metal flux in that water body. Often it appears that not all of the sources, especially where they are diffuse in nature, have been identified.

- Systematic and consistent scoping studies of water bodies impacted by abandoned non-coal mines, including detailed monitoring of water quality and flow, are therefore recommended. Detailed guidance on the approach to such investigations is provided in Report XII: *Future management of abandoned non-coal mine water discharges*. The effects on aquatic ecosystems should also be investigated. If remediation measures are implemented without understanding the dynamics of mining pollution in specific catchments, the environmental objectives for water bodies that are set out in RBMPs may not be achieved despite significant expenditure on engineering works and treatment systems.

- Although we sometimes refer to 'priority for remediation' and 'priority for further data collection' for *Impacted* and *Probably Impacted* water bodies respectively, the reality is that additional monitoring programmes will be a necessity at almost *all* of the water bodies in which non-coal mine drainage is identified as an issue. This is because data collection programmes to date have either not been systematic enough to characterise metal fluxes in water bodies, or have not been appropriately targeted to facilitate the design of a treatment system (or both).

- The passive mine water treatment technologies that have been applied with great success to the remediation of coal mine drainage (principally for the removal of iron) will not work to anything like the same degree for the metals in non-coal mine drainage (e.g. zinc (Zn), cadmium (Cd)). These metals are more soluble than iron and so it is more difficult to remove them from the mine water.

- Effective passive treatment of non-coal mine drainage to consistently meet Environmental Quality Standards (EQS), within a practical land area, is a subject of ongoing research. There are many active treatment technologies that could remediate non-coal mine drainage to the standards required to meet EQS, but they come at a high cost, and in many of the locations of major non-coal mine water discharges it appears unlikely that they would be acceptable developments.

- Irrespective of the type of technology, the management of the metal-rich sludge arising from the treatment of non-coal mine drainage remains a problem. Only active treatment technologies currently offer the possibility of recovering metals in sufficient purity that they *might* be recycled, but even for active systems it currently seems unlikely that recycling of metals from abandoned non-coal mine water

treatment will be economically viable. There may be re-use options for metal-rich media recovered from mine water treatment systems, but these need further investigation.

- There are other problems associated with former non-coal mining districts besides mine water pollution, albeit in some cases these issues may contribute to problems of water pollution. Stability concerns, safety, airborne pollution, and other human and animal health risks, may be significant, and should therefore be addressed accordingly. The level of detail of information provided with respect to these issues has been very varied. Although there are clearly important specific issues relating to these aspects of abandoned non-coal mines that need to be addressed (e.g. stability concerns at specific sites), the main conclusion of this project is that there needs to be a systematic national approach to the assessment of such problems. As well as identifying the most important problems to address, this will directly serve the requirement in the EU Mining Waste Directive to create an inventory of closed mine waste facilities causing harm to human health or the environment.

- The problems evident at abandoned non-coal mines are multifarious and complex. A chronology of environmental management activities for tackling the problems is therefore proposed (Report XII). This sets out the specific requirements of investigations of water pollution problems in abandoned non-coal mine districts, whilst also taking into consideration other potential issues that may be present in such catchments. It is estimated that it will take approximately 4.5 years to complete an individual remediation scheme, from commencement of a scoping study to completion of a full-scale treatment system. Detailed discussion is provided on the exact requirements of investigations targeted at identifying appropriate remedial strategies (i.e. scoping and feasibility stages).

- Conducting thorough investigations of environmental problems in abandoned non-coal mining districts can be expensive. This cost is minor, however, compared to the design, installation and operation of systems to remediate such pollution problems. The total cost to remediate all of the water-related environmental problems associated with abandoned non-coal mines that have been identified as part of this project, is estimated to be approximately £370 million over an initial 10 year period, at present day costs, with additional subsequent operating costs. Of this total around 90% is apportioned to mine water treatment, and 10% to mitigation of outbreak risk and diffuse pollution problems. Treatment systems are likely to be required to operate in perpetuity. There are considerable uncertainties regarding the accuracy of this estimate, due in large part to a paucity of quantitative data on abandoned non-coal mine environmental problems (especially relating to mine water discharge flow and volume).

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1. Introduction

This report presents the outcome of the national surveys assessing outbreak risk (i.e. sudden catastrophic release of polluted water) and solid waste issues at abandoned non-coal mines in England and Wales. The data return is based on feedback from Environment Agency local area staff during the regional assessment exercise (online questionnaire) and from Local Council / Local Authority specialists via an email survey.

The report is broken down into four sections:

- Chapter 2 overview of data return
- Chapter 3: mine water outbreak risk – extent and management options
- Chapter 4: other solid waste hazards and issues
- Chapter 5: summary

This is one of the 13 reports that detail the final results of the implementation of the methodology across England and Wales. The reports are listed below:

I. *A methodology for identification and prioritisation of abandoned non-coal mines in England and Wales*
II. *Prioritisation of abandoned non-coal mine impacts on the environment: The national picture*
III. *Prioritisation of abandoned non-coal mine impacts on the environment in the Dee River Basin District*
IV. *Prioritisation of abandoned non-coal mine impacts on the environment in the Northumbria River Basin District*
V. *Prioritisation of abandoned non-coal mine impacts on the environment in the South West River Basin District*
VI. *Prioritisation of abandoned non-coal mine impacts on the environment in the Western Wales River Basin District*
VII. *Prioritisation of abandoned non-coal mine impacts on the environment in the Humber River Basin District*
VIII. *Prioritisation of abandoned non-coal mine impacts on the environment in the North West River Basin District*
IX. *Prioritisation of abandoned non-coal mine impacts on the environment in the Severn River Basin District*
X. *Prioritisation of abandoned non-coal mine impacts on the environment in the Anglian, Thames and South East River Basin Districts*
XI. *Prioritisation of abandoned non-coal mine impacts on the environment in the Solway-Tweed River Basin District*
XII. *Future management of abandoned non-coal mine water discharges*
XIII. *Hazards and risk management at abandoned non-coal mine sites*

2. Overview of data return

A range of data concerning environmental impacts of abandoned non-coal mine sites not already considered in the water body prioritisation exercise have been collated

on a national basis. These issues are detailed in Table 1 and encompass acute impacts such as risk of sudden release of large volumes of mine water to solid waste issues such as stability, safety and other threats to public health. The database will be of utility in feeding into the mine waste inventories demanded as part of the recently implemented EU Mining Waste Directive (European Community, 2006).

The data return from the Environment Agency and local authorities has been merged (where common data were collected) into a final mine site database called "defra_merged_mines". As with any survey exercise relying on data return from multiple respondents, the data must be viewed with a degree of caution in terms of completeness and accuracy. The database is a dynamic body of information and it will be an ongoing process beyond the timescale of this project to collate data for which so far there has been a poor data return.

Table 1. Issues addressed by the two groups of respondents

Issue	Data input
Outbreak Risk	Environment Agency (EA) local specialists
Stability concerns	EA local specialists & local authorities
Safety concerns	EA local specialists & local authorities
Airborne pollution risk	EA local specialists & local authorities
Other Public / Animal Health issues	Local authorities
Inspections under Part 2A of Environmental Protection Act	EA local specialists & local authorities

Although the Environment Agency has some responsibilities under Part 2A, Local Authorities are the lead regulators. They produce strategies explaining how they will identify and inspect potentially contaminated land in their area, and are responsible for deciding whether land falls under the legal definition of "contaminated land". Local Authorities also have the primary responsibility for ensuring that remediation takes place and deciding who is liable for the costs.

Of the 387 local authorities approached, responses were received from 99 County, District and Borough Councils, with 26 noting the presence of abandoned non-coal mines within their boundary. Importantly, there was a detailed response from many of the main former metal mining regions, with particularly detailed data returns coming from Caerphilly, Caradon, Ceredigion, Mendip, Teignbridge, South Hams, Tynedale and West Somerset. Notable former mining areas without a response include the Yorkshire Pennines, South Pennines and Cumbria. ***Given such disparities in data return between regions, the responses detailed in chapter 3 and Table 2 must be viewed with caution and almost certainly underestimate the potential risks and hazards across England and Wales***. This re-emphasises the need for the database to continue to evolve beyond the timeframe of the project reported upon here.

Additionally, some of the data show clearly erroneous patterns. For example, the Environment Agency data return for the Severn River Basin District included a number of "Suspected" or "Yes" responses to outbreak risk, which on closer reflection appear to reflect only sites where there currently is a mine water discharge

– as opposed to sites where there is a risk of a sudden outbreak. While the data return is reported in its entirety in the database, a screening of the outbreak data has taken place to provide only entries with confirmed outbreak risk below (Table 2).

3. Mine water outbreak risk

3.1 Background

The risk of a sudden outbreak of a large volume of contaminated mine water from a mine site is a key factor in assessing acute future environmental and socio-economic impacts of abandoned non coal mines. A review of sites to identify where there was potential risk of sudden outbreak was undertaken during the regional assessment phase. Respondents at the Environment Agency were asked to populate responses for the outbreak risk category for individual mine sites. A Yes-Suspected-No dropdown menu provided a simple means for data sorting (null responses are deemed to be unknown), while an adjacent open text field in the questionnaire permitted end-users to provide technical details or data sources.

3.2 Recent examples and impacts

3.2.1. The Wheal Jane outbreak

The most serious example of sudden mine water outbreak occurred from the former Wheal Jane tin mine in Cornwall on 13th January 1992. The site has since been the subject of extensive publicly-funded research investigations into the impacts of the outbreak as well as treatability of the discharge. The background to the outbreak and subsequent impacts have been detailed at length (e.g. NRA, 1994; Bowen *et al*., 1998; Younger *et al*., 2005) and hereafter follows a brief description taken from Younger *et al.* (2005).

First records of mining at Wheal Jane date back to 1778, with significant expansion in operations occurring in the early 1960s. Formal closure of the site came in September 1991, due to falling global tin prices and the significant and costly dewatering burden at the site (>200L/s) owing to its connection to an extensive network of long-abandoned mines. Following cessation of pumping (March 1991) water levels gradually rose and by November 1991 the water level was near surface and so limited pumping was commenced on 16th November 1991 from one of the mine shafts, with discharge of the pumped water into the Clemows Valley Tailings Dam, which was still operative at this time, as it received tailings derived from the processing of ores brought to the site from the South Crofty mine, which was still in production. On 17th November 1991, water started to issue from the nearby Janes Adit and on the 20th November 1991 the adit was plugged. Treatment was suspended on 4th January 1992, due to the high turbidity of water discharged from the CVTD, and the mine water was allowed to accumulate in the abandoned workings. On 13th January 1992, an uncontrolled release of a very large volume (variously estimated at between 25,000 and 50,000 m^3 in a 24-h period) of metal laden, acidic mine water occurred from the Nangiles Adit into the Carnon River. Although this outburst was widely attributed to failure of a plug in the portal of the

Nangiles Adit (e.g. NRA, 1994; Bowen et al., 1998), subsequent investigations have shown that no such plug existed and the abruptness of the outburst was actually due to the sudden failure of a pile of roof-fall debris which had been impounding the acidic water above the invert level of the Nangiles Adit (Younger, 2002). The released water contained in excess of 3500 mg/l of dissolved metals / metalloids (principally iron, zinc, cadmium, arsenic, aluminium, plus other traces of toxic metals) which led to downstream Environmental Quality Standards being substantially breached and completely overwhelmed the dilution capacity of all recipient water courses. A highly conspicuous ochre-rich orange plume of contaminated water developed subsequently in the Fal Estuary (Figure 1).

Various treatment options were investigated and trialled before an initial temporary and then permanent treatment plants were built; the most cost-effective technology being oxidation and chemical neutralisation in a lime-dosing high density sludge plant. This treatment plant is currently operating at an annual cost in the region of £1.5 million and has treated in excess of 3 million cubic metres of contaminated water to date since commissioning in 2000.

Figure 1. Aerial view of the Fal Estuary following the 1992 Wheal Jane outbreak

3.2.2. Other examples

There have been numerous other examples of recent outbreak from abandoned mines (both coal and non-coal) in the UK. The Sheephouse Wood discharge near Stocksbridge (South Yorkshire) provides one of the best examples of the potential impacts of such events. In February 2002, a sudden outburst of contaminated water and rubble occurred from Sheephouse Wood into the Little Don River, presumably the result of water building up behind a temporary blockage in the adit, and resulted in a section of the A616 Stocksbridge by-pass being destroyed, and then closed for three days for repairs (Figure 2). Adjacent farm land was also damaged by the outbreak. Fortunately the outbreak occurred overnight when the road was not in heavy use. A range of short term measures to limit immediate impacts of the

outbreak and longer term site management to prevent future blow out has been undertaken by The Coal Authority and is detailed in Section 3.5 (Management and mitigation of outbreak risk).

Figure 2. Outbreak of coal mine water at Sheephouse Wood on the 28th February 2002 showing impact on A616. Photos courtesy of IMC Consulting Engineers.

Similar coal mine outbreaks have occurred at Jackson's Bridge near Holmfirth (South Yorkshire) where cyclical breakouts typically follow heavy rain and at Lowlands (near Cockfield, County Durham) in June 2000, when a shaft collapsed following an intense multi-day rainfall event. The subsequent outbreak at Lowlands led to short-term, severe contamination (principally with iron) of the River Gaunless along a 20km reach to the confluence with the Wear.

Many of the main non-coal mine sites where outbreak has occurred are summarised in the results section below.

3.3 Outbreak risk – results from the abandoned non-coal mine project

Figure 3 shows the geographic distribution of all the mine sites where outbreak risk was at least suspected to be a possibility which amounts to a total of 74 mine sites (18 'yes', 56 'suspected' responses). However, the 31 mine site entries for the Severn RBD suggest a misunderstanding of the question and reflect only sites where there is or potentially could be a mine water discharge (as opposed to acute impacts of sudden outbreak). Furthermore, 'suspected' responses received for 18 mine sites

in upper Teesdale and on the Cleveland Ironstone field did not report any details on the outbreak concern; it is likely that the precautionary approach taken for outbreak risk and solid waste issues at all the sites in the southern part of the Northumbria RBD is due to lack of detailed information about the mines. On closer inspection only 19 of these (9 'suspected', 10 'yes' responses) provide any level of detail from which to confirm the extent of the risk. These sites are displayed in Table 2.

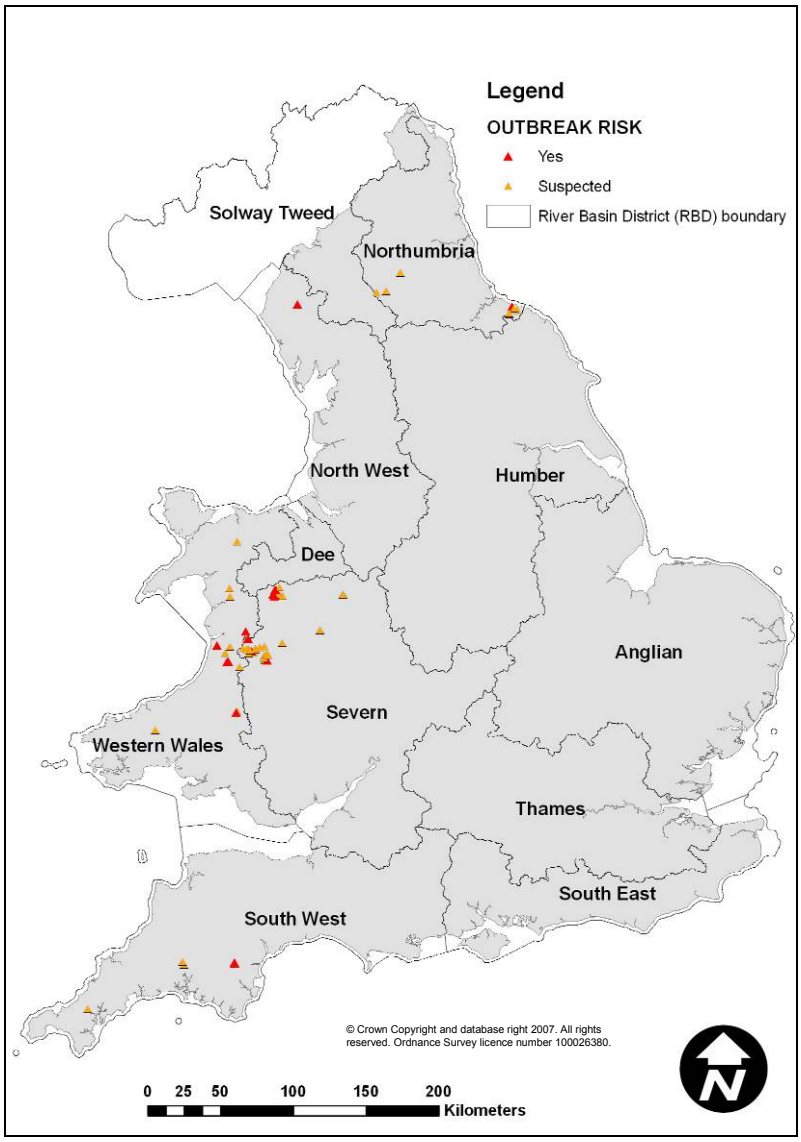

Figure 3. Abandoned non-coal mine sites where there was perceived risk of outbreak – results of regional assessment.

Table 2 highlights the issues reported where details were provided for sites returning a Yes or 'suspected' response. Typical issues highlighted include flooded shafts with water at higher elevations than recipient water courses and drainage adits (e.g. Force Crag, Cwm Rheidol, Dylife, Nant y Mwyn), underground blockages (e.g. Glasdir, Gwaithcoch, Parc), previous history of outbreak in the area and other evidence of instability in shallow workings which could create conditions conducive to breakout. At two sites (Nant y Mwyn and Caegynon) issues of upwelling under high flow are explicitly mentioned.

At sites with history of outbreak, the Stormsdown, Union and Brothers mines can be viewed together as they all drain into a tributary of the River Lemon and were subject to a sudden outbreak in 2004 after a suspected mine collapse.

The Rispey site in the Rookhope Burn is also mentioned as a site with history of outbreak. The metal mines of the North Pennines have experienced several incidences of recent mine water outbreak which usually follow extreme rainfall events. The Rispey outbreak occurred in December 2006 and was considered to be due to obstruction of the adjacent (and hitherto flowing) Tailrace Level discharge. This forced the collapse of a nearby crown hole from which the discharge newly emerged to the Rookhope Burn (Figure 4). This new discharge is now the second most severe metal mine water in the North Pennines in terms of zinc loading, discharging in the region of 4.5 tonnes of zinc per year into the Rookhope Burn and subsequently the River Wear.

Figure 4. Outbreak from Rispey siderite mine in County Durham which occurred following heavy rainfall in December 2006.

Another comparable incident occurred nearby at Rookhope in April 2005. Following 98.5mm of rainfall in 48 hours and subsequent increase in river flows, former mine workings under the Rookhope Burn collapsed. Large volumes of water subsequently leaked through the workings and emerged from another entry point to the mine on the Boltsburn Old West Level. Diversionary river works were necessary to limit the flow of water into the workings. These incidences are fairly typical in karstified (fissured) and heavily mined terrain such as that found in the Carboniferous limestones of the North Pennines, where workings are susceptible to rapid ingress of waters in high flow which can contribute to conditions conducive to breakout.

Beyond the metal mines, some instability in shallow workings has also been noted in the Cleveland Ironstone field (Northumbria RBD) at the North Skelton / Longacres mines. Recent outbreak following redirection of an existing discharge at Saltburn Gill does suggest some instability and conditions potentially conducive to sudden breakout.

Table 2. Abandoned non-coal mine sites in England and Wales where there is a known or suspected risk of mine water outbreak (not in priority order)

Water body ID	RBD	Water body name	Easting	Northing	Mine name	Outbreak risk	Outbreak risk comments
GB112075070440	North West	Newlands Beck	320000	521630	Force Crag	Yes	Adit blockage, & overflowing crownhole on steep ground, minewater outbreak risk
GB103025071960	Northumbria	Saltburn Gill	467300	520200	North Skelton/ Longacres	Yes	Instability in shallow workings. Noted impact on nearby SSSI also concerns on local tourism impact
GB108046008450	South West	River Lemon	276970	72960	Stormsdown	Yes	Pollution incident logged in 2004 – ochreous slug of water released after apparent mine collapse.
GB108046008450	South West	River Lemon	277050	73200	Union	Yes	Pollution incident logged in 2004 – ochreous slug of water released after apparent mine collapse.
GB108046008450	South West	River Lemon	276800	73360	Brothers	Yes	Pollution incident logged in 2004 – ochreous slug of water released after apparent mine collapse.
GB110060036350	Western Wales	Tywi (Doethie to Gwydderig)	278200	243800	Nant y Mwyn Deep Boat Level	Yes	Adit 'fountains' to about 15ft in high flows
GB110060036350	Western Wales	Tywi (Doethie to Gwydderig)	278746	244463	Nant y Mwyn	Suspected	Deep boat level 'fountains' about 15ft in high flows
GB110063041570	Western Wales	Rheidol (Castell to tidal limit)	271800	278400	Caegynon	Yes	Suspicious upwelling in highway in high flows near buried adit
GB110063041570	Western Wales	Rheidol (Castell to tidal limit)	272919	278154	Cwm Rheidol	Yes	Adit 9 unless it is drained down, Adit 6 if stream breaks in to workings
GB110064048320	Western Wales	Twymyn – upper	286128	293957	Dylife	Yes	There is a flooded shaft on site above the level of the river
GB210064043630	Western Wales	Leri	264800	289400	Alltycrib	Yes	Only if adit does collapse - it's full of water with no outfall at present
GB103024077530	Northumbria	Rookhope Burn	390860	542920	Rispey Mine	Suspected	Outbreak history in area
GB108047007860	South West	Lower River Tamar	241380	74040	Devon Great United	Suspected	Being monitored for movement
GB109054049480	Severn	Minsterley Brook	335500	299500	Tankerville	Suspected	Possible potential of shaft fill resulting in outbreak, Concern on possible outbreak if collapse happens
GB110063041610	Western Wales	Clarach	270500	284200	Gwaithcoch	Suspected	There is a concreted off adit just below the lake. the miners blocked it
GB110063041720	Western Wales	Ystwyth	280200	274600	Cwmystwyth	Suspected	Effluent may be emerging in river bed
GB110064048730	Western Wales	Mawddach – middle	273861	322564	Glasdir Mine	Suspected	It is alleged that there is an underground dam.
GB110064054620	Western Wales	Mawddach – upper	273600	328200	Gwynfynydd	Suspected	If pipe blocks
GB110066060030	Western Wales	Nant Gwydir (Conwy)	278700	360200	Parc	Suspected	Suspected underground blockage

3.4 Potential impacts of outbreak

The hazards and risks associated with potential outbreak from abandoned non-coal mines depend on numerous factors including:

1. the presence of any infrastructure in the immediate vicinity of the outbreak (e.g. roads, paths, buildings)
2. the time the outbreak occurs (in terms of human activity: e.g. on roads / footpaths)
3. the volume and quality of mine water released
4. the size of the recipient water course(s) and flow rate at time of outbreak (dilution capacity)
5. the presence of potentially sensitive ecological communities in downstream surface waters

In terms of the risk of occurrence of outbreaks in the future, it is not possible to rule out the possibility of such events occurring, particularly at those sites identified in Table 2. Those sites at which there is an observed head of water above a potential discharge point (e.g. Force Crag, Dylife) probably present the highest risk, and should therefore be priorities for intervention. Beyond this, the likelihood of future outbreak occurrences at non-coal mines similar to the incidents at Sheephouse Wood and Wheal Jane appears low, for the following reasons:

- Unlike the Sheephouse Wood coal mine water outbreak example detailed above, most of the non-coal mine sites with known outbreak risk are in sparsely populated upland settings. As such there is only minimal risk of outbreak severely affecting trunk infrastructure (e.g. major roads). However, this does not totally preclude the possibility of serious impacts on property or public in addition to potentially severe environmental impacts on receiving water courses (e.g. Force Crag in Cumbria – see section 3.5).

- The mechanisms causing outbreak episodes are varied and the example of Wheal Jane is not necessarily a typical reflection of other non-coal mine sites. The cessation of pumping when the active mining operations at Wheal Jane stopped was followed by a rapid build up of mine water due to the very large area of interconnected workings. This situation is unlikely to recur since groundwater levels are expected to have recovered decades ago within other non-coal mines, and few mines receive drainage from such a large area.

In many of the upland mining settings (e.g. North Pennines, Western Wales) previous outbreaks have occurred following intense rainfall events (e.g. Rispey, Boltsburn Level in Rookhope Burn), or conditions conducive to breakout have been reported under high flow (e.g. Nant-y-Mwyn, Caegynon). In the North Pennine examples outbreaks have tended to occur at times when the dilution capacity of recipient streams is very high due to high flow rates, therefore limiting the measurable impact. However, the long term residual pollution can be worse than pre-existing states (due to new drainage paths in hitherto dry levels flushing out contaminants) and therefore a cause for concern. Additionally, given the increased severity and incidence of multi-day rainfall events predicted to occur with current and

future climate change, the risk of outbreak could conceivably become more apparent in some areas.

3.5 Management and mitigation of risk of outbreak

The management of risk at sites where there is at least the possibility of major outbreak is highly dependent on the nature of the issue and the site and the hydrogeological context to breakout. In some of the upland settings where outbreak has occurred it has followed extreme rainfall and the collapse in shallow workings. Recent examples (e.g. Rispey, Rookhope) were not subject to intense monitoring in the build up to the events and as such the episodes appeared largely unpredictable. Management in such cases was therefore responsive and confined to short term works to make safe the initial hazard (e.g. fencing off newly emerged crown holes, diversionary river works where there is major ingress into workings). Long term management would benefit from a thorough review and assessment of recent outbreaks (hydrological and hydrogeological context) as well as monitoring at sites to aid prediction of sites where outbreak risk is heightened.

At numerous other sites (e.g. Cwm Rheidol, Dylife, Force Crag) there are fairly long-standing issues of perched mine water being impounded due to blockage of adits. Here, the location of potential outbreak and/or slope collapse can be fairly well-defined and subject to a series of monitoring and preventative remedial efforts where necessary. ***It is recommended that investigations should be carried out at the sites identified in Table 2 to determine the likelihood of the outbreak occurring.*** Options for managing and minimising risk of outbreak are detailed below:

1. Monitoring flow rates and / or water levels

   In cases where there is sudden collapse in shallow workings / adit blockage a fall in flow rates from a pre-existing discharge can be indicative of a build-up in hydraulic head in the workings and a precursor to breakout. Similarly, a steady rise in water levels in shafts would also indicate potential obstructions to drainage that may create conditions conducive to blow-out.

2. Monitoring for movement in shallow workings

   The use of seismic monitoring devices can be suitable for assessing movement in areas of workings known to be unstable. Such approaches would be particularly applicable where instabilities are likely to lead to sudden breakout of water or surface subsidence that could impact on infrastructure / public health (e.g. the Alltycrib mine in the Leri catchment, Western Wales – see section 4.2).

3. Remedial engineering works to minimise hazard

Engineering works to relieve a build-up of contaminated water behind an obstruction is a problem at several abandoned non-coal mine sites and is a problem currently being addressed in some cases. Experience of the Coal Authority in managing similar hazards in coal mines also offers an indication of preventative and remedial measures that can be employed.

An example of current management of outbreak risk at a non-coal mine is at the Force Crag lead mine in Cumbria where the site owners (National Trust) have

commissioned investigations to assess options to relieve impounded mine water. Some 20 metres of mine water has built up behind a collapsed adit in the lowest level of the workings. Along with evidence of physical instability in saturated slopes and recent changes in flow at the site, the blockage has prompted fears of a sudden slope collapse which could release at least a portion of the ~400m^3 of zinc-rich mine water that is thought to be impounded in the mine into the adjacent Coledale Beck (and subsequently into Bassenthwaite Lake). While such an outbreak would be of particular concern in such a sensitive setting with downstream conservation sites (Figure 5a), directly beneath the area of impounded water are preserved mine buildings and a public footpath / roadway so there are also concerns for public safety (Figure 5b). As such, the National Trust has initiated investigations to reduce the head of mine water. These have comprised detailed review of mine site hydrogeology, water quality and engineering options. The proposed option for relieving the mine water build-up is temporary pumping of water from the lowest mine level via a new borehole, to then allow drilling of a new replacement adit entrance which would permit long term gravity-driven drainage of the mine.

Figure 5. The Force Crag lead mine (circled) in the Coledale Valley (left) showing the steep terrain and mine buildings (right)

More advanced operations have been undertaken by the Coal Authority in addressing outbreak risk at Sheephouse Wood, South Yorkshire. Immediately following the outbreak, site works were focussed at minimising impacts and making the site safe. These works included installation of twin large diameter pipes under the A616 in an effort to minimise damage to the road in the event of a recurrence of the outbreak, reinstatement of road itself, construction of drainage ditches across adjacent farmland, and pollution mitigation measures to protect the receiving watercourse (River Little Don). The total cost of these actions was approximately £50,000. Long term management at the site was focussed at preventing future outbreak events. A vertical borehole was installed into the adit to allow concrete to be pumped between two stoppings to form a concrete plug (incorporating drainage pipes) within the adit, and a protective headwall was constructed immediately outside the adit mouth. To facilitate these works, which commenced in 2004/5, a borehole was put into the mine workings and the mine water was over-pumped for approaching 1 year (2004/5) to lower the head of water in the workings. The costs of the initial borehole were in the region of £15,000, with pumping costs for a standalone generator at the site around £2,500 per month. The protective headwall and adit engineering works cost an approximate further £68,000. Thus, the total cost

of the operation following the outbreak (assuming 1 year of pumping) was £163,000. Designs for a treatment system for the discharged water from the site are currently being finalised.

4. Other solid waste hazards and issues

4.1 Stability Concerns

A total of 72 mine sites returned an affirmative (Yes or 'Suspected') response for stability concerns. Over half of the 'suspected' responses did not provide any details on the nature of the stability concern. In some cases the stability concerns are repeated in the safety and even outbreak risk categories. 42% of the documented Yes responses were associated with areas of riparian spoil which are being scoured by rivers (Table 3). This is a common feature of many former metal mining areas and poses a significant risk also for diffuse contaminant input into surface waters under high flow conditions. Other stability issues are associated with instability in shallow workings (and associated surface subsidence), ingress of surface drainage channels into workings (see Outbreak Risk) and stability of spoil heaps due to steep slopes (in the absence of fluvial erosion).

Table 3. Responses received for abandoned non-coal mine sites where there are stability concerns

Response	Yes	Suspected
Total number of mine sites	26	46
No details given	1	25
Spoil heaps / tailings being scoured by river	11	9
Shaft collapse / general instability in workings / fill material	6	6
River flowing into workings	4	0
Concern over stability of tailings dam / spoil heaps	4	5
Steep terrain	0	1

The bulk of the mine sites where stability issues have been highlighted fall within the Western Wales and North Pennine orefields (Figure 6). Stability issues were also noted in the South West (Wheal Andrew, Mount Wellington), Northumbria (Saltburn Gill in the Cleveland ironstone Field), Western Wales (Parys Mountain, Gwynfynydd), Severn (Tankerville), North West (Force Crag), Anglian (ironstone mines in north Lincolnshire and Irthlingborough), and Thames (clay and chalk mines near Wycombe).

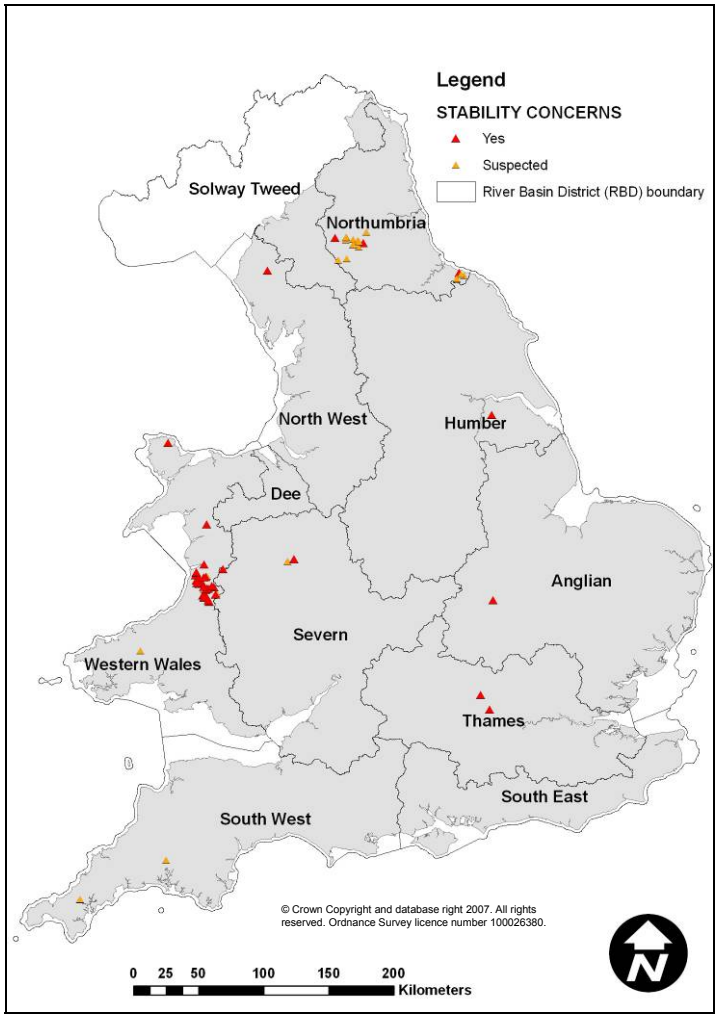

Figure 6. Abandoned non-coal mine sites where there are stability concerns – results of regional assessment.

4.2 Safety concerns

A total of 160 mines returned a Yes or 'Suspected' response for safety concerns. The majority of these (57% of Yes, 93% of 'Suspected') did not provide details as to the nature of the safety concern. Where detail was provided, the safety issues covered a range of factors (see Table 4) but were predominantly related to open shafts and stopes, instabilities in spoil heaps or shallow workings and informal after-use of mine sites for mountain biking and 4 wheel drive vehicle use. Other issues that were reported included mine buildings being at risk of collapse due to river erosion (Nant y Creiau, Western Wales) and exposed metal-rich fines (Esgairmwyn Old, Western Wales). In a small number of cases examples of previous or potential impacts on infrastructure are given. For example at the Alltycrib mine in Western Wales where an adit under a class A road in Talybont village is known to have unstable brickwork, and at the Pwll Roman mine site, which again falls within the Leri catchment in Western Wales, where a shaft collapse has been reported close to a domestic dwelling.

The bulk of the reported safety concerns fall with the district of Ceredigion and in Western Wales in general (Figure 7). This partly reflects the quality and extent of the

data return in these areas. A small number of mines in Northumbria (North Pennines and Cleveland Ironstone field), the South West and the Force Crag site in the North West RBD are also highlighted with safety issues.

Table 4. Responses received for abandoned non-coal mine sites where there are safety concerns.

Response	Yes	Suspected
Total number of mine sites	63	97
No details given	36	90
Open shafts or stopes	7	1
Inappropriate use by 4x4 / mountain bikes	7	0
Concern over collapse of spoil	5	5
Unstable shafts	5	0
Mine buildings undermined by river	2	0
High concentration of metals in exposed fines	1	0
Bathers using polluted stream	0	1

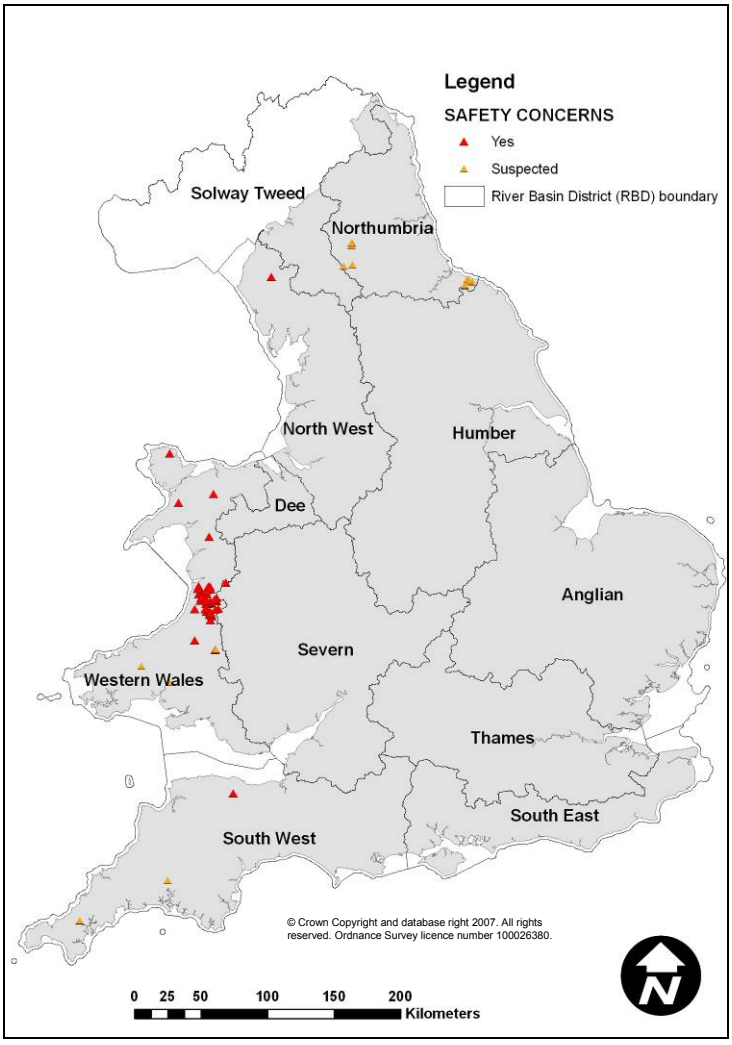

Figure 7. Abandoned non-coal mine sites where there are safety concerns – results of regional assessment.

4.3 Airborne Pollution Risk

The assessment of airborne pollution risk is concerned with impacts of dust blow from exposed metal-rich spoil, particularly in areas close to, or used by the public. A total of 382 mine sites returned an affirmative response for airborne pollution risk, the vast majority of which (90% of Yes responses, 61% of 'suspected' responses) did not provide detail on the type of the risk (Table 5). Given the nature of the question, however, it would be reasonable to assume there are exposed fines/ spoil at these sites. Where information was provided it typically confirmed the concerns of exposed fines that would be susceptible to dust-blow. At four sites (e.g. Frongoch, Esgairlle, Pandora New and Grogwynion all in Western Wales) the risk of surface erosion was noted to be exacerbated by informal recreational mine site after-uses such as by mountain bikes or off-road vehicles, while at two other sites (Welsh Potosi and Esgairffraith in the Lluestgota water body in Western Wales) mine spoil appears to be used as construction material for private roadways. At one site, Parys Mountain (Mynydd Parys, Western Wales) investigations are currently ongoing by Ynys Mon Council to assess implications on human health of wind blown dust from dried out ochre pits that impacts nearby residential dwellings.

The geographic distribution of the sites with airborne pollution risks (Figure 8) shows a large number being highlighted in the North Pennines (Northumbria RBD) and in Western Wales. 259 mine sites were highlighted by Caradon District Council in south east Cornwall as having airborne pollution concerns but no details are provided as to the nature of the concern.

Table 5. Responses received for abandoned non-coal mine sites where there are airborne pollution concerns

Response	Yes	Suspected
Total number of mine sites	294	88
No details given	264	54
Exposed spoil / fines	24	34
Spoil erosion exacerbated by mountain bikes / 4x4	4	0
Exposed spoil used in roadways	2	0

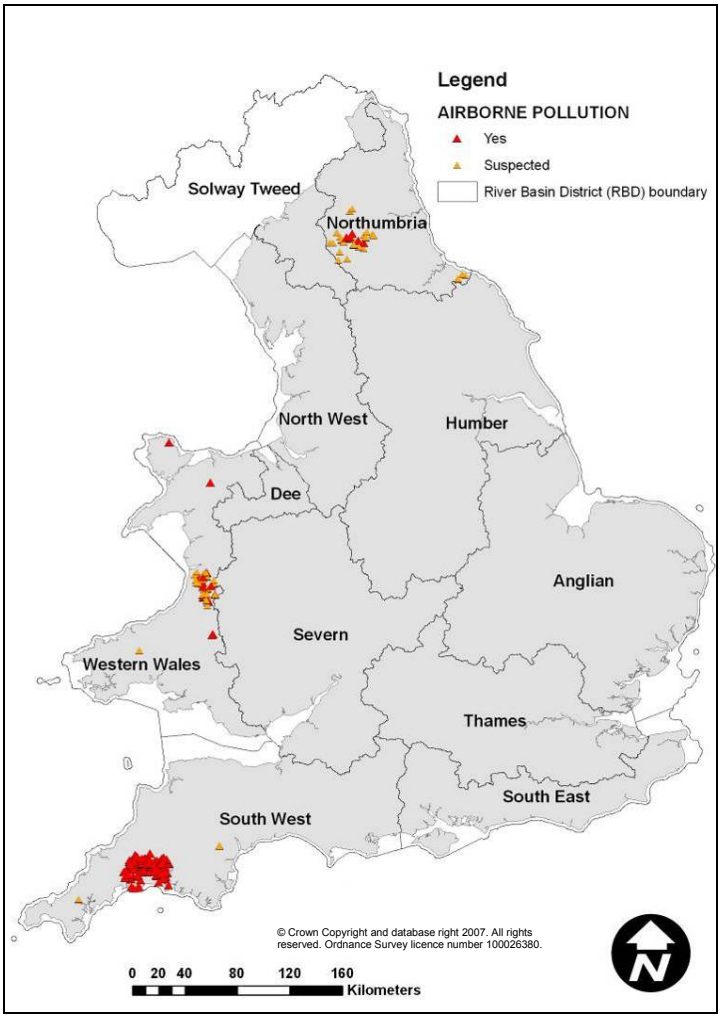

Figure 8. Abandoned non-coal mine sites where there are airborne pollution concerns – results of regional assessment.

4.4 Public / Animal Health Impacts

The Local Council / Local Authority respondents were asked the additional question as to whether there were any other potential impacts of abandoned non-coal mine sites of public or animal health. In total 86 sites were identified with an affirmative (yes or 'suspected' – see Table 6). 6 sites in Northumbria were identified as having potential impacts due to agricultural after-uses of abandoned mine sites, with a further one used as a domestic garden. A large number (44) of 'suspected' responses were given for the metal mines in Ceredigion but with no further details as to the nature of the risk.

Table 6. Responses received for abandoned non-coal mine sites where there are additional public and/or animal health concerns

Response	Yes	Suspected
Total number of mine sites	42	44
No details given	37	44
Farming / agricultural after use on mine site	4	0
Domestic garden after use on mine site	1	0

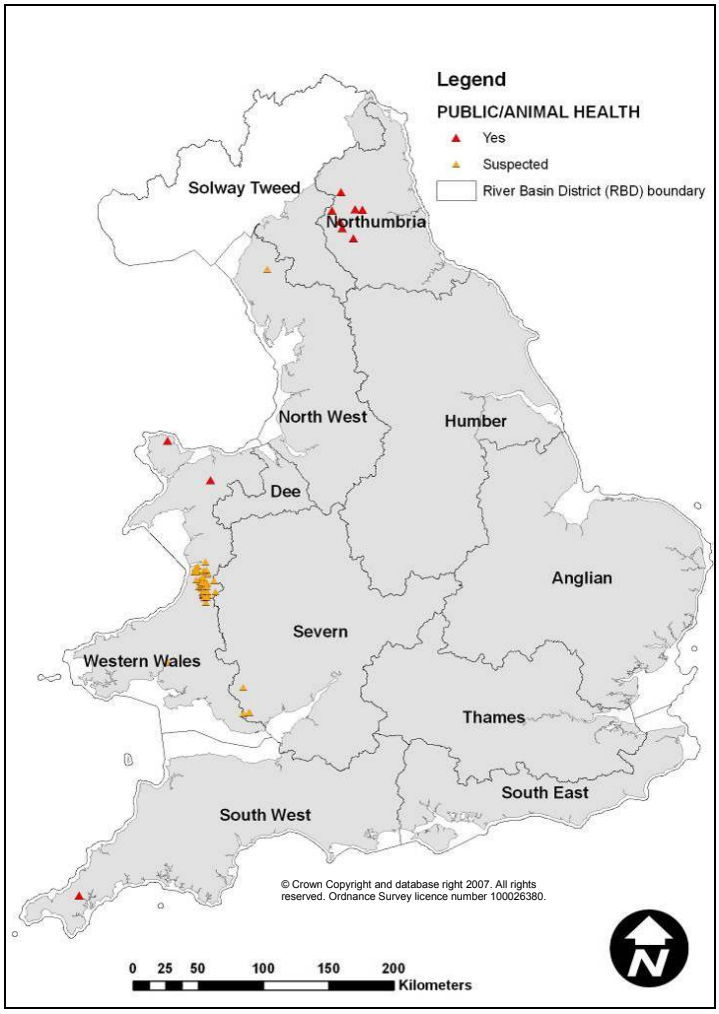

Figure 9. Abandoned non-coal mine sites where there are public / animal health concerns – results of regional assessment.

4.5 Part 2A Inspections (Contaminated Land regulations)

Local council and local Environment Agency staff were also asked to identify those sites which are currently, or are proposed to be investigated under Part 2A of the Environmental Protection Act. The data return showed that 522 abandoned non-coal mine sites were under consideration to be investigated under Part 2A. The geographic distribution of the sites (Figure 10) again reflects the disparities in data response between the different RBDs and councils, with the Ceredigion and Caerphilly county councils providing particularly detailed responses.

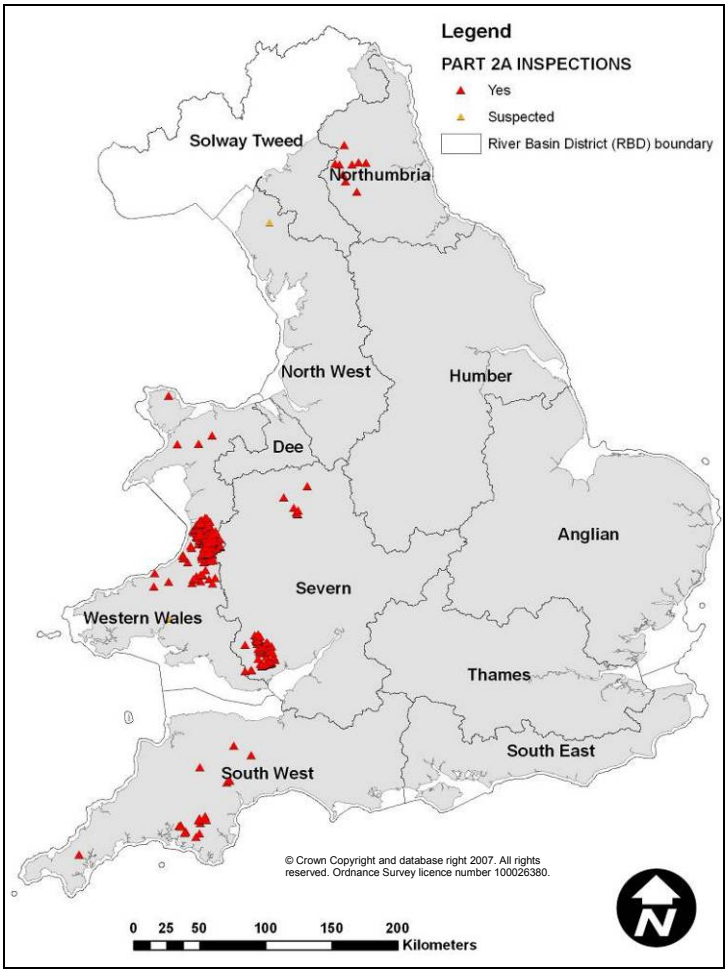

Figure 10. Abandoned non-coal mine sites proposed to be assessed under Part 2A of Environmental Protection Act – results of regional assessment

4.6 Management options at mine sites with solid waste hazard issues

At many of the mine sites identified as posing a risk due to some variety of solid waste hazard it is likely that little formal investigative work has been undertaken to properly characterise the nature of the hazard(s) and risk(s). It has already been noted at a number of points through this report that the responses received to the questions have been mixed, for example in the level of detail provided, and the extent to which respondents have taken a precautionary approach in answering questions. With the advent of the Mining Waste Directive there is a strong case for having a nationally systematic approach to assessing solid waste hazards and risks at abandoned non-coal mine sites.

There is a considerable body of literature relating risk assessment at contaminated land sites, including guidance documents on such assessments produced by government and regulatory authorities. Such information could be the starting point for developing a nationally-applicable screening methodology for identifying abandoned non-coal mine sites where genuine hazards and risks are present, e.g.

where the potential for exposure of humans or animals to contaminated wastes exceeds a certain threshold.

At those sites exceeding the predefined threshold limits further investigations could then be instigated, such as:

- Monitoring quality of windblown material using appropriate monitoring equipment (which is routinely undertaken at operational open cast mine sites)
- Detailed risk assessments where public / animal health concerns exist, including identification of exposure pathways and such like

Logically such investigations would then be followed by remedial works, such as installation of dry covers to cap fine materials which would otherwise generate airborne pollution problems, and securing other areas (e.g. fencing) where there is a clear risk to animal and human health e.g. open shafts and stopes.

With regard to physical issues of slope stability the Coal Authority has a regular programme of tip inspections (as do local authorities), which it would be imagined could be easily modified to address the specific issues at abandoned non-coal mine sites. For an experienced engineer the assessment of geotechnical risks, for example by identifying areas of rotational slippage, slumping and so forth, is comparatively straightforward, and allows subsequent engineering works to be appropriately targeted. Such engineering works would likely include slope stabilisation / reprofiling / regrading, and ensuring drainage channels under and around tips are open and well maintained.

Finally, issues of stability may overlap with risks of diffuse pollution where spoil heaps and other abandoned non-coal mine features are immediately adjacent to water courses, due to erosion during storm events resulting in bank collapse and potentially large inputs of (contaminated) sediment into the water course. River bank stabilisation works, using geotextiles, rip-rap and gabions, are discussed briefly in the accompanying report *XII. Future management of abandoned non-coal mine water discharges*.

5. Summary

This report presents the outcome of surveys of Environment Agency and Local Authority staff on outbreak risk and solid waste issues at abandoned non-coal mine sites; data returns are known to be incomplete and are expected to underestimate the potential risks across England and Wales.

Outbreak risk

- 10 sites are known to represent an outbreak risk
- 9 sites are suspected of posing an outbreak risk
- Investigations should be carried out at these sites (Table 2) to determine the likelihood of the outbreak occurring.

Solid waste hazards and issues

- 72 sites were identified as having potential stability concerns
- 160 sites have potential safety concerns
- 382 sites have a potential risk of airborne pollution
- 86 sites have possible public or animal health impacts
- 522 sites are being considered for investigation under the Part 2A Contaminated Land regime

The information in this report should contribute to the inventory of closed and abandoned waste facilities required by the Mining Waste Directive

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