Report on the Options for Control of Mine Water in the East of Wear Area

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1 INTRODUCTION

This report, undertaken on behalf of the Coal Authority, was requested by the Liaison Group concerned with mine water recovery and the prevention of contamination of the Permian aquifer in the East of Wear area. The purpose of the report is to determine the options that are available for mine water control then assess the sites technically in terms of the optimum method for mine water treatment. It is proposed that the information provided by the report would be used by the Liaison Group to determine where mine water is to be controlled and how it should be treated following completion of the period of temporary pumping currently being undertaken at Horden. The Planning Permission for the current temporary pumping at Horden runs out in April 2006.

The report is based on the information currently available. However, further investigations and research will continue to ensure the optimum site(s) for pumping and the method(s) of mine water treatment are selected. As further data become available they will be included in the both the decision making and the design of the pumping site(s) and the method of treatment. The report does not take into account the availability of land or visual impact of the alternative methods of mine water treatment.

This report does not cover the risks and potential methods of control and treatment of mine water discharges inland to the River Wear.

2 THE TEMPORARY MINE WATER PUMPING AND TREATMENT AT HORDEN COLLIERY

Mine water levels in the East of Wear area are currently controlled by temporary pumping at Horden Colliery. The mine waters are treated by means of an active plant that principally removes iron from the water. Following the commissioning of the active treatment plant in July, mine water has been pumped at a rate of approximately 45 L/sec. At the rate of 45 L/sec, mine water levels were initially drawn down about 3 metres at Horden (See Figure 1). The drawdown at Horden stabilised and the abstraction rate was increased to 65 L/sec on 4 October to further lower the mine water level relative to the water level in the Permian aquifer.

The mine water pumping at Horden has influenced mine water recovery at Easington, Dawdon and Hawthorn (See Figure 2). The interaction between the pumping at Horden and the water levels at Easington, Dawdon and Hawthorn shows that the abstraction of mine water at Horden has reduced the flow to the other collieries. This infers that the flow path of the mine water must be through Horden to the other collieries, even though the single mining connection between Horden and Easington was dammed. If the current mine water flow paths persist, mine water pumping at Horden can be used to control mine water levels below the Permian in the East of Wear area adjacent to the coast.

The quality of the mine water when 45 L/sec was pumped from Horden Shaft and treated in the active plant was very similar to the mine water that was pumped during the initial test in January 2004. The total iron in the raw mine water was about 45 mg/L. This is reduced to less than 1.0 mg/L by the active treatment before being discharged to the sea. The chloride concentrations of the raw mine water were around 4,000 mg/L. The chlorides are not affected by active mine water treatment and are discharged to the sea at similar concentrations. The chemistry of the raw mine water confirms that the deeper mine waters with high chloride and iron concentrations are not being disturbed by the pumping at Horden when abstraction rates of around 50 L/sec are used. The quality of the mine water pumped at Horden with an abstraction rate of 50 L/sec is such that it could probably be treated passively using aeration, settlement ponds, and an aerobic wetland (reed beds). Research is currently being undertaken into the growth of reed beds in moderate salinity waters.

The quality of the mine water when the abstraction at Horden was increased to 65 L/sec on 4 October to further lower the water level in the mine workings has deteriorated from 45 mg/L of iron to about 75 mg/L. The chloride has risen, but only from 4,000 mg/L to about 5,000 mg/L (based on on-site conductivity measurements). The laboratory analyses of the chloride concentrations are currently awaited.

3 FURTHER INVESTIGATIONS PROPOSED DURING THE TEMPORARY HORDEN PUMPING

Following the success at Horden in pumping shallow, less contaminated mine water, it is proposed to carry out a similar test at Dawdon Colliery using Northumbrian Water's long sea outfall for the discharge. The pumping test at Dawdon will help to determine the suitability of the site for pumping and allow the quality of the mine water to be checked. The water quality will help to assess the options available for mine water treatment should Dawdon be used for pumping. The test will involve initially pumping at Dawdon on its own and then in tandem with Horden. Work has begun at Dawdon and the shaft caps have been exposed to determine the works required to install pumps and build the connecting pipe work. The plan to carry out a similar pumping test at Hawthorn appears not to be possible because of the lack of a suitable pipe for the contaminated mine water discharge in the vicinity of Hawthorn Shafts.

The sampling of mine water quality will continue at Horden and at Dawdon during the pumping test. Further fluid conductivity and temperature logs and discrete water samples will be taken from the open shafts during the pumping tests at Horden and Dawdon.

4 METHODS AVAILABLE FOR TREATMENT OF MINE WATER

The current pumping of mine water at Horden and the resultant drawdown at Horden, Easington, Dawdon and Hawthorn has shown that abstracting 50 L/sec of water is not sufficient to completely stop mine water recovery in the long-term. Further increases in the pumping rate will be made to determine the abstraction rate that will be required. Based on current information, the best estimate of the required pumping rate is 100 L/sec.

Based on the quality of the mine water pumped at Horden, the qualities observed in the other open shafts and the anticipated abstraction rate of around 100 L/sec, there are considered to be four principal methods available for mine water treatment in the East of Wear area. (See Table 1.) The four options are:-

1) **A passive treatment using aeration, settlement lagoons and aerobic wetland (reed beds).**

Based on the information currently available, this system is the most environmentally sustainable. However, this system can only be used where the mine waters have chloride levels below about 5,000 mg/L as above this level there is currently no certainty that reed beds will survive. Research into reeds tolerant of more saline water is continuing.

The area of land required for a passive treatment system with an aerobic wetland will depend on the rate of abstraction of the mine water and the quality. However as a guide, based on the rate and quality of mine water pumped at Horden, 50 L/sec with 50 mg/L of iron, the total area required would be between 10,000 and 12,000 m^2, of which approximately half would be settlement lagoons and half reed beds. If 100 L/sec of mine water at 100 mg/L of iron could be treated, the area of land required would be 18,000 – 20,000 m^2.

2) **A passive system using aeration and settlement lagoons only.**

A passive system without reed beds could be used where the mine waters have chloride levels above the tolerance level of reeds.

The area of land required for a passive system using settlement only will again depend on the mine water abstraction rate and quality. As a guide, again using 50 L/sec and 50 mg/L of iron the total area of land required would again be in the range of 10,000 to 12,000 m^2, depending on the level of iron required for the discharge. The treatment area would comprise only settlement lagoons. If 100 L/sec of mine water at 100 mg/L of iron was pumped and treated, the area of land required would be 18,000 – 20,000 m^2.

3) **A passive system using aeration and settlement lagoons with the addition of chemicals**

A passive system using aeration and settlement lagoons with the addition of chemicals would be required if the mine water became acidic. The chemicals are used to increase alkalinity and ensure the iron can be removed in the settlement lagoons. The treatment area required would be the same as options 1 and 2 for abstractions of 50 L/sec and 100 L/sec of mine water.

4) **An active treatment plant similar to that in current use at Horden**

The active treatment plant is an industrial process that mixes chemicals with the mine water in 6 metre high reaction tanks and uses flocculent and clarifiers to remove the iron precipitate.

The active treatment plant has the greatest use of chemicals. The system requires only about 5,000m^2 of land and can cope with a wide range of water qualities and flows.

Appended to this report are plans that show the areas of land required for each of the different mine water treatment options detailed above at the same scale (1/25,000) as plans of the various pumping site options.

Table 1 Methods of Mine Water Treatment

Treatment Option	Area of land Required to Treat 50 L/sec Fe (m^2)	Area of land Required to Treat 100 L/sec Fe (m^2)	Chemical Usage	Mine Water Composition	Additional Requirements
1. Passive Treatment with Reed Beds	10,000 to 12,000	18,000 to 20,000	Good if no chemicals used	Low chloride concentration (<5000 mg/L). Net alkaline. Circumneutral pH.	Caustic addition maybe required if pH becomes acidic.
2. Passive Treatment without Reed Beds	10,000 to 12,000	18,000 to 20,000	Good if no chemicals used	Net alkaline. Circumneutral pH.	Caustic addition maybe required if pH becomes acidic.
3. Passive Treatment with chemicals	10,000 to 12,000	18,000 to 20,000	Moderate to poor	Any quality	Caustic soda and flocculant
4. Active Treatment	5,000	5,000	Poor	Any Quality	Alkali & flocculant agents

4.1 Relative Costs of Passive and Active Mine Water Treatment

The cost of mine water treatment can be divided into three areas, the purchase of land, construction and running costs. The cost associated with each item is dependant on the quality and quantity of the mine water to be treated. To compare the costs of the different methods of treatment available, flows of 50 L/sec with 50 mg/L of iron and 100 L/sec with 100 mg/L of iron have been used. The estimated costs are listed below in Table 2.

The land costs are based on the areas defined in section 3 of the report and an estimated "ball park" land cost of £10,000 per acre. One acre is 4,047m^2. The land costs vary from about £12,500 for the land for an active treatment plant as at Horden, to £50,000 for an area of 20,000 m^2 for a large passive site.

Construction costs vary from £450,000 for a small passive area capable of treating 50 L/sec of mine water with an iron concentration of 50 mg/L to £1,300,000 for the active plant with a capacity of 100 L/sec.

Running costs are where there are significant variations in cost over time. These vary from just over £55,000 per annum for a small (50 L/sec) passive system to £415,000 p.a. for the active plant capable of treating 100 L/sec. It should be remembered that the expected pumping rate to control the mine water is about 100 L/sec. Therefore two 50 L/sec pumping and treatment systems or one 100 L/sec system will be required.

Table 2 Relative costs of the different methods of Mine Water Treatment

Costs	Passive Treatment with Reed Beds		Passive Treatment without Reed Beds		Passive Treatment without Reed Beds & Chemicals		Active Treatment Plant with Chemicals	
	50 L/sec / 50 mg/L Fe	100 L/sec / 100mg/L Fe	50 L/sec / 50 mg/L Fe	100 L/sec / 100mg/L Fe	50 L/sec / 50 mg/L Fe	100 L/sec / 100mg/L Fe	50 L/sec / 50 mg/L Fe	100 L/sec / 100mg/L Fe
Land Purchase £10,000 per acre 1 acre = 4047m^2	£30,000	£50,000	£30,000	£50,000	£30,000	£50,000	£12,500	£12,500
Construction Costs	£500,000	£1,000,000	£450,000	£900,000	£530,000	£1,030,000	£1,060,000	£1,300,000
Running Costs/Year	£58,000	£102,000	£56,000	£100,000	£116,000	£203,000	£150,000	£415,000
Total Cost over 5 years	£820,000 (=£164,000/y)	£1,560,000 (=£312,000/yr)	£760,000 (=£152,000/yr)	£1,450,000 (=£290,000/y)	£1,140,000 (=£228,000/yr)	£2,095,000 (=£419,000/yr}	£1,822,500 (=£264,500/yr)	£3,387,500 (=£677,500/yr)
Total Cost over 25 years	£1,980,000 (=£79,200/yr)	£3,600,000 (=£144.000/yr)	£1,880,000 (=£75,200/yr)	£3,450,000 (=£138,000/yr)	£3,460,000 (=£138,400/yr)	£6,155,000 (=£246,200/yr)	£4,822,500 (=£192,900/yr)	£11,687,500 (=£467,500/yr)

The active plant costs assume that the 50 L/sec plant will have two 50L/sec streams and the 100 L/sec plant three 50 L/sec streams.

5 AN ASSESSMENT OF THE POTENTIAL SITES FOR CONTROL AND TREATMENT OF MINE WATER IN THE EAST OF WEAR AREA

There are four open mine shafts available in the East of Wear area for the pumping of mine water. They are at Dawdon, Easington, Hawthorn and Horden. The only other alternative would be to drill a large diameter borehole into a suitable underground roadway with good hydraulic connection. The various options for control of mine water by pumping at the individual sites and combinations of sites are discussed below, based mainly on current knowledge, but taking likely changes in mine water flows and pathways into consideration.

The principal variations to flows and pathways are likely to occur due to changes in relative mine water levels between the coastal collieries (Horden, Easington, Dawdon and Hawthorn) and the inland workings represented by Sherburn Hill, Nicholsons, Lumley 6th and Chatershaugh. Since pumping started at Horden water levels at the coast have stabilised or have been lowered. (See Figure 1.) The continuing slow rise in mine water levels at the inland collieries will soon result in the water levels at all the inland collieries being higher than the water levels at the coastal collieries. This will probably result in an increase in the flow rate of mine water to the coastal collieries and potentially a change in the chemistry of the water.

5.1 Assessment of Sites

The sites have been assessed based on the current information available and changes that are considered will occur over time. The assessment includes each sites potential to control minewater in the East of Wear, the quality of the water that will be abstracted, the type of treatment that could be used, the availability of land and the position and quality of the water at the discharge. No specific areas of land have been identified at this stage.

5.1.1 Horden Colliery

The temporary pumping and treatment scheme at Horden Colliery has provided the first hard information on pumped mine water quality and interaction between Horden, Easington, Dawdon and Hawthorn.

The current information available for Horden would suggest that:-

a) Mine water pumping at Horden could be used to control mine water levels in the East of Wear area to prevent contamination of the Permian aquifer.

b) An abstraction rate of 50 L/sec does not draw the deeper mine waters with the high levels of chloride (> 50,000 mg/L) sampled at 380 metres depth in Horden Shaft prior to starting pumping.

Based on a pumping rate of about 50 L/sec and an iron concentration of 50 mg/L, the mine water abstracted at Horden could be treated passively including an aerobic wetland (reed beds) in an area of approximately 12,000 m^2.

c) It is likely that at some stage in the future, the pumping rate required to control mine water at Horden may have to be increased significantly to about 100 L/sec. At this flow rate, passive mine water treatment that included reed beds would probably not be an option due to the increase in chloride concentrations. An active plant similar to the current treatment system at Horden or a passive treatment system without reed beds would be required.

d) There is an existing mine water discharge pipe to low water that could be utilised for pumping to the east of the railway and for the final discharge to the sea of treated mine water.

5.1.2 Easington Colliery

The open shaft at Easington Colliery has good connection with Horden Shaft based on the information provided by the Horden pumping, with mine water currently flowing from Horden to Easington at the Low Main horizon.

The current level of information available at Easington would suggest that:-

a) Mine water pumping at Easington could be used to control mine water levels in the East of Wear area to prevent contamination of the Permian aquifer.

b) It is possible that an abstraction rate of 50 L/sec would not draw the deeper mine waters with the higher levels of chloride (> 50,000 mg/L) sampled at 380 metres depth in Horden Shaft prior to starting pumping. However no discrete water sampling was carried out in the shaft at Easington, only at Horden, Dawdon and Hawthorn. Therefore it is not possible to guarantee the water quality that would be abstracted.

c) It is likely that at some stage in the future, the pumping rate required to control mine water from Easington may have to be significantly increased to about 100 L/sec. At this flow rate,

passive mine water treatment that included reed beds would probably not be an option due to the increase in chloride concentrations. An active plant similar to the current treatment system at Horden or aeration and settlement without reed beds would probably be required.

d) There is no pipe at Easington that could be utilised for the discharge of treated mine water. A new pipe to low water would be required.

5.1.3 Dawdon

The current temporary mine water pumping at Horden has demonstrated interconnection between Horden and Dawdon via Easington. The horizons(s) at which mine water flows between Easington and Dawdon is not known. However, because of the greater depth of the mine workings at Dawdon, any abstraction at Dawdon may, at least initially, draw mine water with high chlorides. The proposed pumping test at Dawdon should confirm the initial quality of pumped mine water.

The current level of information would suggest that:-

a) Mine water pumping at Dawdon could be used to control mine water levels in the East of Wear to prevent contamination of the Permian aquifer.

b) It is considered likely that any abstraction rate at Dawdon will give chloride concentrations that are too high to be treated by a passive system that includes reed beds. An active treatment system or passive treatment without reed beds would be required.

c) It is likely that at some stage in the future, the pumping rate required to control mine water from Dawdon would have to be significantly increased (100 L/sec). The water quality would be expected to deteriorate.

d) Discharge to the sea from any treatment at Dawdon could be via the Northumbrian Water long sea outfall.

5.1.4. Hawthorn Colliery

Hawthorn Colliery has been shown by the temporary pumping at Horden to be interconnected with the three coastal collieries. This infers that at present a significant proportion of the mine water inflow at Hawthorn flows via Horden, Easington and Dawdon.

The current information available for Hawthorn would suggest that:-

a) Mine water pumping at Hawthorn could be used to control mine water levels in the East of Wear area to prevent contamination of the Permian aquifer.

b) It is possible that an abstraction rate of 50 L/sec would not draw the deeper mine waters with the higher levels of chloride (> 50,000 mg/L) that occur below 160m BOD in Hawthorn Shaft.

   It is possible that using a similar abstraction rate to Horden (50 L/sec) mine water could be pumped that could be treated passively. However, the chloride levels are likely to be still too high after treatment for discharge to a local water course and would require a discharge pipe to the sea.

c) It is likely that at some stage in the future, the pumping rate to control minewater from Hawthorn would have to be significantly increased (100 L/sec). At this flow rate chloride concentrations are likely to increase. If chloride levels increased, then an active plant similar to that currently in use at Horden or passive treatment without reed beds would be required.

d) There is no suitable mine water discharge pipe available at Hawthorn. To plan and construct a new discharge pipe for pumping at Hawthorn would require a minimum of 3 years and would not be available when the temporary pumping at Horden is due to finish.

5.1.5 Large Diameter Borehole

The site for a large diameter borehole has been previously investigated and a site identified on the coast near to Hawthorn Quarry. This is the only site that could be identified on the coast other than drilling near the existing open shafts at Horden, Easington and Dawdon. The borehole would contact the upper horizon roads connected to Hawthorn Shaft.

For this assessment it has been assumed that there is insufficient time to guarantee a borehole could be completed. However one could be drilled at a later date and linked to an existing treatment scheme constructed south of Dawdon.

The current information available for the large diameter borehole site would suggest that:-

a) Mine water pumping at the large diameter borehole site could be used to control mine water levels in the East of Wear area to prevent contamination of the Permian aquifer.

b) It is possible that an abstraction rate of 50 L/sec would not draw the deeper mine waters with the higher levels of chloride (> 50,000 mg/L) that occur below 160m BOD in Hawthorn Shaft.

It is possible that using a similar abstraction rate to Horden (50 L/sec) mine water could be pumped that could be treated passively. However, the chloride levels are likely to be still too high after treatment for discharge to a local water course and would require a discharge pipe to the sea.

c) It is likely that at some stage in the future, the pumping rate to control minewater from the borehole would have to be significantly increased (100 L/sec). At this flow rate chloride concentrations are likely to increase. If chloride levels increased, then an active plant similar to that currently in use at Horden or passive treatment without reed beds would be required.

d) There is no pipe at the large diameter borehole site that could be used for mine water discharge. A new pipe to low water would be required.

Table 3 Pumping Site Assessment

Site	Will pumping at this site alone control mine water levels	What abstraction rate will be required	Can the mine water be treated passively with reed beds	Can the mine water be treated passively without reed beds	Can the mine water be treated with an active plant	Is there an existing pipe for mine water discharge
HORDEN	YES	~100 L/sec	PROBABLY But maximum 50 L/sec	YES but chemicals may be required for 100 L/sec	YES	YES
EASINGTON	YES	~100 L/sec	POSSIBLY but flow rate not known	YES but chemicals may be required for 100 L/sec	YES	NO 800m pipe required
DAWDON	YES	~100 L/sec	PROBABLY No	YES but chemicals may be required for 100 L/sec	YES	YES (NWL)
HAWTHORN	YES	~100 L/sec	POSSIBLY but flow rate not known	YES but chemicals may be required for 100 L/sec	YES	NO 5,700m pipe required
LARGE DIAMETER BOREHOLE	YES Subject to good connection to mine workings	~100 L/sec	POSSIBLY but flow rate not known	YES but chemicals may be required for 100 L/sec	YES	NO 700m pipe required

6 ALTERNATIVE SCHEMES TO REPLACE HORDEN TEMPORARY PUMPING

Based on the current level of information, and assuming a pumping rate of 100 L/sec, the following options are still available:-

1 An active treatment plant sited at Horden, Easington, Dawdon, Hawthorn or a new large diameter borehole.

2 Passive treatment system comprising aeration and large settlement lagoons with or without chemical additives sited at Horden, Easington, Dawdon, Hawthorn or a new large diameter borehole.

3 A passive treatment system comprising aeration, settlement lagoons and reed beds (aerobic wetland) at Horden (Max. 50 L/sec) combined with either an active plant (option 1) or a passive system using settlement lagoons (option 2) at Easington, Dawdon, Hawthorn or a new large diameter borehole.

The information detailed in section 5 has been used to rank the various options in terms of the land required, time before the the site could be operational, long term costs and the environmental sustainability of the schemes. (See Table 4.).

Based on this assessment, the best technical options for control and treatment of mine water are;-

a) To have a large active plant sited at Dawdon, Easington or Horden,

or

b) To have a combination of a small passive treatment system (probably with reed beds) at Horden with a smaller active plant at Dawdon or Easington.

The advantages of a single active treatment site for control are in the early stages with only a limited area of land being required and there is a proven flexible system available. The disadvantages of a single active plant are the long term cost and the lack of flexibility should unforeseen changes occur to flow paths or water quality.

The advantages of a two site approach using different treatment methods would be flexibility both in pumping and the type of treatment and a substantial reduction in longer term in running costs. The passive system using reed beds is also the most environmentally sustainable of any of the options available. The disadvantages are in the area of land required for the passive treatment at Horden and the initial construction costs.

Table 4 Overall Assessment of Sites and Treatment

	Site and Minewater Treatment Option	Area of Land Required	Time before Operational	Long-Term Cost/25 Years	Environmental Sustainability	Total Score	COMMENTS
Active Treatment							**WILL WORK AT ANY SITE**
1	HORDEN	1	1 (in place)	2 or 3	3	7 - 8	
2	EASINGTON	1	1	2 or 3	3	7 - 8	
3	DAWDON	1	1	2 or 3	3	7 - 8	
4	HAWTHORN	1	3	2 or 3	3	9 - 10	
5	LARGE DIAMETER BOREHOLE	1	2	2 or 3	3	8 - 9	
Passive Treatment with Chemicals							**WILL WORK AT ANY SITE**
6	HORDEN	2 or 3	2	2 or 3	2 or 3	8 - 11	
7	EASINGTON	2 or 3	2	2 or 3	2 or 3	8 - 11	
8	DAWDON	2 or 3	2	2 or 3	2 or 3	8 - 11	
9	HAWTHORN	2 or 3	3	2 or 3	2 or 3	9 - 12	
10	LARGE DIAMETER BOREHOLE	2 or 3	2	2 or 3	2 or 3	8 - 11	
Passive Treatment without reed beds (possibly part-treatment only)							**WILL ONLY WORK IF WATER NOT ACIDIC**
11	HORDEN	2 or 3	2	1	1	6 - 8	100 L/sec flow may become acidic
12	EASINGTON	2 or 3	2	1	1	6 - 8	100 L/sec flow may become acidic
13	DAWDON	2 or 3	2	1	1	6 - 8	100 L/sec flow may become acidic
14	HAWTHORN	2 or 3	3	1	1	7 - 9	100 L/sec flow may become acidic
15	LARGE DIAMETER BOREHOLE	2 or 3	2	1	1	6 - 8	100 L/sec flow may become acidic
Passive Treatment with reed beds (possibly part-treatment only)							**WILL ONLY WORK IF WATER LOW CHLORIDE AND NOT ACIDIC**
16	HORDEN	2	2	1	1	6	50 L/sec probable maximum
17	EASINGTON	2	2	1	1	6	Chloride levels probably too high
18	DAWDON	2	2	1	1	6	Chloride levels probably too high
19	HAWTHORN	2	3	1	1	7	Chloride levels not proven
20	LARGE DIAMETER BOREHOLE	2	2	1	1	6	Chloride levels not proven

1. *5,000m2 (1.25 Acres)*
2. *12,000m2 (3.0 Acres)*
3. *20,000m2 (5.0 Acres)*

1. *< 1 year*
2. *1 - 2 years*
3. *> 2 years (Cannot replace Horden*

1 *<£200,000 pa*
2 *£200,000 - £400,000 pa*
3 *>£400,000 pa*

1. *Good (no chemicals)*
2. *Moderate (limited chemicals*
3. *Poor (high use of chemicals)*

 Insufficient time to replace Horden