Henton, M. P. (1976): Predicting the quality of mine water discharges. – Effluent & Water Treatment Journal, 16 (11): 568, 572, 1 Tab.; London.

Predicting the quality of mine water discharges

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MINE WATER discharges in the Fife Region cause the Forth River Purification Board considerable pollution control problems which are likely to continue for several years to come. There are three main sources of mine waters; firstly, pumped water from deep mines; secondly, pumped water from opencast coal workings and, lastly, discharges from old drainage adits.

Fife has a long history of mining in two separate coalfields, east and west Fife and in recent years has suffered a considerable decline in the industry with the cessation of mining over most of central and east Fife. Only two working pits are left in this area now although several pits are used for pumping to protect the remaining workings.

In west Fife also there have been a large number of pit closures which were counteracted to some extent by the opening of a series of mines known collectively as the Hurst complex which are joined together underground and principally serve Longannet Power Station on the Forth Estuary. This complex is drained by a number of 'bores' which discharge pumped water to surface watercourses.

Owing to the topography watertable rebound has not had as serious effect as it has in the Lanarkshire coalfield[1] but a few day level and other discharges do occur and can cause quite serious local pollution in some of the smaller streams. The last category, water from opencast coal workings, has provided the most serious and intractable problems and is the one which gives rise to future concern. The coalfield geology of Fife is such that it is very suitable for working by opencast mining, particularly where coal remains above old deep mine workings and it appears that several more opencast mines will be opening up in the next few years. It was because of the water pollution problems caused by opencasting in the past that an attempt has been made to gather together all the existing data on ferruginous discharges in Fife and to try to establish a pattern from which the quality of water from new sites could be predicted. If this could be done then it would be of value to the River Purification Board in its water quality management programme and to the operator in deciding upon the amount of treatment required prior to discharge. At the present time the work is only theoretical but it does seem that it has possibilities in practice. It is hoped to try out the theory when two new opencast sites come up for consideration in the next few months.

Data sources

The aim is to gather together all the data relevant to the Fife coalfields as a whole and then to supplement this with the information specifically applicable to the site under consideration. From this it is hoped that water quality predictions can be made. Even if these turn out to be fairly crude, they should indicate whether a high or low pH, suspended solids and iron content are likely. Hydrological and hydrogeological records should allow an estimation of water quantity which is as important a factor as water quality.

Geological data are readily available in the published maps and memoirs of the Institute of Geological Sciences (IGS). The coalfield memoirs[2] are quite detailed and often yield useful facts about the individual coal seams. Most opencast sites in Fife work seams have already been extracted by deep mining and so their characteristics are well known. Hydrogeological data is not so easy to come by as groundwater is not considered to be of great importance in Scotland yet, particularly in the coalfield areas. This situation is changing but there will always be a lack of good long-term, reliable hydrogeological data in Central Scotland. Little is known of watertable levels and fluctuations, groundwater movement and water quality. The Geological Survey's Record of Wells is the best attempt at listing groundwater data that is available.[3]

The River Purification Board has water quality records, some of which go back several years as a result of its sampling programme. These records are all concerned with pumped or free flowing groundwaters where they are discharged at the surface and not with the *in situ* groundwater as would be sampled in a borehole. The amount of change in chemical composition of the groundwater which takes place as a result of pumping is not known. The hydrogeochemistry of such waters is complex and it remains to be seen whether or not predictions made from *in situ* water samples relate closely to the water issuing from the pumps at the surface. Most of the changes which occur concern the precipitation of iron and alterations to the pH of the groundwater. There are several published papers describing the chemistry of mine waters.[4]

The water quality records cover all three categories of discharge but naturally there are more records available for the large discharges from working pits and from important 'natural' discharges than for the small 'natural' discharges. In the case of some working opencast sites very little water is produced and so few records are available. A similar situation probably exists in most Water Authority areas. From these sources a basic picture of the groundwater conditions in the area can be drawn up.

The specific information which it would be useful to obtain at each opencast or deep mine site includes watertable levels and seasonal fluctuations, chemical analyses of the *in situ* groundwater, and a knowledge of the surface hydrology and its relation to the local groundwater system. The names of the coal seams to be worked and access to the drillers' log sheets for the site to assess the type of strata, particularly any ironstone and water-bearing sandstone beds, would be useful but may not be easy to get. The major seam names alone would suffice if the site is in an existing

coalfield when the IGS memoir could be consulted for details of the strata. In a new coalfield access to the more detailed data would be essential.

Water quality at existing discharge points in Fife

The results of the chemical analyses of samples taken from existing sites in the three categories in Fife are shown in Table 1 (See Appendix I). The figures for category 1 are for the unsettled pit water as it comes to the surface whilst those for the opencast sites are for settled mine waters. In one of the opencast sites the chemical composition of the water alters as it moves through the site. No detailed analyses are available but the quality varies from the point of issue, through the sump at the bottom of the site to the discharge to the settling ponds at the top with pH and iron content changing most.

Some of the figures in Table 1 are averages taken from the last year's sampling programme, except in the case of category 3 when most discharges have been sampled for the first time. Flow figures are not available for all the sites but in general the pumped mine water discharges are of the order 0·05–0·1 m^3/s whilst the discharges from old drainage adits are much smaller. The opencast sites vary widely, from 0·15 m^3/s down to minimal flows depending upon the local conditions prevailing at the site.

Several trends emerge from these figures which are useful in determining the general water quality pattern in the Fife coalfields. Firstly, the pumped waters from deep mines in east Fife are more iron-rich than those of west Fife. This is backed up by evidence from two other pumping stations inland from the collieries for which figures are not available but which have very iron rich waters. The mine waters of west Fife have never caused any pollution problems. The east Fife pits work the Productive Coal Measures and the Limestone Coal Group, whilst west Fife is mainly the Upper Limestone Group. The stratigraphy of the carboniferous rocks in Scotland differs from that in the rest of the country and will not be discussed in detail.[5]

Secondly, opencast sites give rise to waters which are highly variable in quality and quantity. The quantity of water pumped from an opencast site depends on factors which have been mentioned previously. In Fife the topography and geology give rise to sites which are fairly dry, especially where they work no deeper than 100 m. With a few exceptions, past and present opencast sites are working the Limestone Coal Group as will the future sites. Westfield Opencast Site is exceptional in that Lower Coal Measures and Passage Group coals are extracted in a deep synclinal site over 250 m in depth. It is here that the problem of iron contamination of groundwater can be seen clearly. The strata contains many iron-rich beds and some old workings which discharge a typical acid mine water into the pumping sump. The depth of the site contributes to the problem as it is well below the regional water table. A large breached fault in the north wall produces a good flow of crystal clear pure water which well illustrates how the host strata determines the groundwater quality.

Lastly, acid mine waters discharging from old drainage adits, as a result of watertable rebound are of very poor quality regardless of their geographical situation. This is a fairly common occurrence in all coalfields and certainly in the Scottish coalfields discharges of this kind, which are of good quality, are the exception rather than the rule. This category is not particularly relevant to the present work.

Future predictions and conclusions

Mine water quality prediction work is only in its early stages in the Fife area but it is hoped to try it on a working site in the near future. The overall pattern of groundwater quality in a coalfield area must first be established and a broad outline of this has been completed for the Fife coalfield. The next step is to obtain the relevant data for each new site and to try to relate this to the overall pattern. From this a rough idea of the quantity and quality can be obtained and consultations regarding the treatment and disposal of the water can be carried out between the relevant water authority and the contractor. This work could be of economic value to the contractor when tendering for a site and to the Water Authority in its pollution prevention programme. ■

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Acknowledgement

The author wishes to thank W F Collett, River Inspector, Forth River Purification Board for his permission to publish this paper. The views expressed therein are the author's and do not necessarily represent those of the River Purification Board.

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Appendix 1

Table 1

Coalfield	*Name*	*Temp*	*pH*	*Total SS mg/l*	*Total Iron mg/l*	
Category 1 Pumped water from deep mines						
East Fife	Seafield Colliery	16·0	7·0	438	18	
,, ,,	Frances Colliery	16·0	7·0	165	14	
West Fife	Solsgirth Mine	13·0	7·4	58	—	
,, ,,	W. Saline Bore	10·0	7·9	82	3·5	
,, ,,	Piper Pool	13·0	8·2	4	1·2	
,, ,,	Bogside Bore	14·0	8·1	46	2·5	
,, ,,	Keir	13·0	8·0	3	0·8	
Category 2 Discharges from opencast coal sites						
Central Fife	Westfield	8·0	5·3	52	170	
,, ,,	N. Remiltoun	7·5	8·1	14	—	
,, ,,	Dora	7·0	6·8	24	—	
Category 3 Discharges from old drainage adits, etc						*flow* *
East Fife	Burnside Farm	10·0	5·4	94	180	medium
,, ,,	Bour Burn	9·0	3·8	104	100	medium*
,, ,,	Coal Farm	9·5	6·3	39	32	small
West Fife	Outh Bridge	7·0	6·4	14	10	medium*
,, ,,	Forest Mill	7·0	5·8	13	4	medium*
,, ,,	Blairmains Farm	7·0	3·1	72	210	small
,, ,,	Kincardine	10·0	6·8	16	7	v. small

* discharge has serious detrimental effect on the receiving waters.