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APPLICATION OF EXECUTIVE INFORMATION SYSTEM TO MINE SITE WATER POLLUTION CONTROL

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ABSTRACT

The paper oulines the environmental problems associated with coal mine workings in the water catchment area of the Sydney Water, NSW, Australia. The legislative controls to planning, construction and operation of a new mine through imposing lease conditions and financial guarantee by the Department of Minerals Resources, NSW in the environmentally sensitive area in NSW are described. Mining Rehabilitation and Environmental Management Plan (MREMP) is presented which can be used to exercise environmental control on the mining operations. A case history regarding waste water management in a colliery in the Illawarra Region is given together with the suggestions for adopting Information Technology in waste water management.

INTRODUCTION

During the last decade the environment considerations have become a prime concern to society. It has been realised that changes in attitudes towards the environment must be made if sustainable industrial, economic and social development are to be maintained. Such development is specially applicable to the mining industry and particularly to coal. The current dependence of the Australian economy on coal can not be over emphasised as coal is a major export commodity. The problems and sustainability of ecological systems are of fundamental importance to environmentally sustainable mining.

One of the most important coal mining regions of Australia - the Southern Coalfield, which produces some 17 million tonnes, is located within the Illawarra region. The coal mined is a prime hard coking coal, mainly used in the coke ovens at the Port

Kembla and Whyalla steelworks and exported to steelworks in Asia, Europe and South America. Joint Coal Board [1993] . Underground mining is being carried out mostly at the Illawarra escarpment and governed by strict environmental controls. Recently under the auspices of the Mining Act 1992 new mines have to be planned in relation to environmental control from conception to the closure of the mining operations.

Surface water quality information on the mine effluent receiving waters of the Illawarra region is lacking. Since 1990, the University of Wollongong has carried out a study to assess mine effluent water quality in the Illawarra region in order to understand the impact of mine water on natural water courses. In addition to this, the study was designed to identify the sources of water pollution problems and to suggest ways to improve them.

ENVIRONMENTAL MANAGEMENT AND LEGISLATIVE CONTROL OF NEW MINE SITES

Environmental Approach to Mine planning

By its very nature, mining operations disturb the surrounding natural land, air and aquatic environments. Therefore, it is necessary to conduct mining operations with the environmental safe guards and rehabilitate the mine after completion of the mining operations in order to meet the expectations of the community, government and the industry. Mining and exploration, in New South Wales, Australia, may be authorised under any of the following three principal legal authorisation procedures:

(i) A Mining or Coal Lease issued by the Department of Minerals Resources and operated in compliance with the lease conditions.

(ii) By virtue of the private ownership of the mineral and in accordance with the conditions of the development consent. This is implemented by the State Environmental Protection Authority , or,

(iii) Under a title granted under the Crown Lands Act by the Department of Conservation and Land Management.

Thus, in recent years there is a shift in the public expectation that the regulatory authorities should pay emphasis to anticipating and preventing environmental impact due to mining rather than using earlier reactive approach [Anon 1994]. The Department of Mineral Resources is responsible for promoting mining development, management and utilisation of mineral resources in New South Wales. It places emphasis on environmental factors in the planning, operational and rehabilitation phases of mining. This objective is achieved by using a combination of environmental management plans, appropriate conditions on titles and financial guarantees against performance, developed in consultation and co-operation with industry [Burrows, 1994].

Lease Condition and Financial Guarantee

Most mining in New south Wales is authorised by a title issued under the Mining Act 1992. The principal sections of the Act enabling the imposition of conditions are Section 70 - under which a mining operation can not be suspended without written consent of the Minister, Section 273 which protects natural resources, Section 238 which includes conditions for protecting the environment and Section 239- which deals with the rehabilitation of the area damaged by mining. The last condition is particularly important as it permits the Department of Mineral Resources, through the Minister, to vary the environmental or rehabilitation conditions in a mining title.This power of amendment illustrates the importance placed on satisfactory environment performance and is the only way in which a lease condition may unilaterally vary the term of environmental matters only.

Until passing of the 1992 Act, the only available sanction for breaches of the lease conditions was the cancellation of the tenement. While this threat is still pertinent implementation of such threats in reality is highly unlikely. However, the Mines Act 1992, Section 5, has created an offence to carry out mining in contradiction to the conditions of the mining lease issued by the Department of Minerals Resources specified in the Mining Rehabilitation and Environmental Management Plan (MREMP) [Brooks et al 1991].

Mining Rehabilitation and Environmental management

The Mining Rehabilitation and Environmental Management Plan is an essential official vehicle for introducing environmental considerations into mine planning [Brooks et al. 1991]. It prevents adverse effects of mining, reduces environmental cost and provides agreed procedures for rehabilitation of the mine after mining operations have ceased. In order to encourage responsible mine environmental management, the title holders are required to submit as a condition of their title to the Department of Minerals Resources a detailed MREMP for approval. This plan is reviewed annually throughout the life span of the mine. All concerned authorities are represented at a single on-site meeting to discuss the plan with the mine operator's representatives. The plan is then approved as submitted or in a modified form. Compliance with the approved plan is then mandatory, although there is a provision for amendment during the year if circumstances change. The annual reporting procedure is the key element to MREMP. Thus, the Environmental Rehabilitation and Environmental Management Plan provides flexibility to both mine operators and government in response to changing circumstances and increasing knowledge of the local environment. In order to assist the mine operator in the preparation of an MREMP, an extensive set of guidelines are prepared by the Department of Minerals Resources by incorporating both short term mining operational objectives and long term rehabilitation goals of the mine. The scope of the MREMP documentation can be varied with the scale of operations. The Department of Mineral Resources is responsible for overseeing the plan, for co-ordinating the input of various government authorities and ensuring that the mine operations and rehabilitation programs are being carried out in compliance with the lease conditions and the MREMP. The advantages of a Mine Rehabilitation and Environmental Management Plan are as follows:

- The plan incorporates all government actions and compliances in a single documentation, thus avoiding conflicting government requirements and resulting in a single reporting system.

- The agreed MREMP permits rapid evaluation of controls and eliminates unnecessary duplication of efforts by various government authorities and the mine operator.

- For the Department of Mineral Resources , the MREMP ensures that environmental planning is an integral part of mine planning and not introduced as a piecemeal or as of minor importance.

- An annual review and a single combined site inspection meeting eliminates a great deal of the interference and duplication by governmental departments

- Integrated mine planning and environmental management approach has resulted in cost reductions by many mining operations. Thus, MREMP concept is a valuable instrument for assisting both government and industry in the management of the environmental impacts of mining from large gold mines to small intermittently operating quarrying operations.

STUDY OF MINE WATER QUALITY IN A MINING CATCHMENT IN AN ENVIRONMENTALLY SENSITIVE AREA

Natural Environment of the Catchment

The Illawarra region is divided into a coastal and an upland area, stretching along the coast from the Royal National Park in the north, to Durras Water in the south and extends 30km inland. The region incorporates 13 mines and these are located around the city of Wollongong within a radius of 60 km. The city is heavily industrialised and located on a narrow coastal plain which rises as an escarpment to a plateau. A part of the plateau acts as a water supply catchment area for Wollongong and Sydney and has restricted access in many areas. Some mines operate up stream of this catchment area. Some river systems also originate in the plateau and flow eastward to the sea, some into Lake Illawarra and others through the National Parks. Most mines discharge water into the nearest creek/river system. Surface water bodies in this region are already under stress due to various urban developments, and this combined with mining activity means that the threat to the environmental sensitivity of the area can not be overemphasised.

Geology and Climate

The Illawarra coalfield lies in the south-eastern part of the Sydney Basin, where the strata consists mainly of sedimentary rocks of Triassic and Permian age. The strata overlying the Illawarra Coal Measures is a series of interbedded sandstones and shales of the Narrabeen Group. These in turn are overlain by a thick massive sandstone unit, the Hawkesbury Sandstone. The Hawkesbury Sandstone outcrops, covering most surface areas, is overlain in some parts by a thin veneer of Wianamatta shale. Talus slopes extend from the base of the Illawarra escarpment onto the coastal plain.

The Illawarra Coal Measures extend over much of the escarpment. Since the strata is generally only slightly dipping, mostly at only a few degrees, the mines are able to directly follow a coal seam from its outcrop, usually near the top of the lower slopes of the escarpment.

Four significant coal seams have been mined but only two are currently worked - Bulli and Wongawilli Seams. The Tongarra Seam, which is not currently being mined, is the deepest seam. Up to 2.7m of its upper section has been mined in the past. About 30m above, is the Wongawilli Seam, of which about 2.7m of the bottom section of its 11m width is mined. Next is the Balgownie Seam, more irregularly distributed than the other coal seams and with thickness usually about 1.2m or more. The uppermost seam is the Bulli Seam which averages about 2m thickness in the northern part of the area where it is extensively mined.

Rainfall over the area is controlled largely by orographic uplift at the escarpment, and is relatively high. The medium annual rainfall is mostly between 1000 and 1250mm. In places, rainfall is up to 1500mm which is high by Australian annual standards. The wettest months are usually December to April. Maximum monthly temperature generally ranges from about 14°C in July to about 26°C in January. It may also be noted that the 50 year mean rainfall is 1208 mm and the average annual evaporation is about 900mm.

Australian coals tend to be low in most trace elements, partly because of the low content of pyrite and other sulphide minerals and also because extensive mineralisation does not occur near the coal seams. Toxic elements such as arsenic, beryllium, cadmium, mercury and selenium are low in comparison with coals from the eastern United States coal regions. During the extraction of coal from the seam, changes such as oxidation may release trace metals to ground and surface waters.

Field Sampling Program

The field sampling program is designed to comply with the two primary aims: one to study the mine effluent water quality and secondly to assess the impact this mine effluent water has on local waterways. Normally three principal sampling locations are chosen for each mine; **S1** upstream of any mining influence, (in some cases becomes the make-up water used for that mine) ; **S2** mine discharge and **S3** is downstream from the discharge and any mining outfall. At each sampling location approximately 4.5 litres of sample are taken. Two x 2 litre polyethylene containers and 1x0.5 litre polyethylene container are used. One of the 2 litre containers is kept free of any preservatives. Whereas the second sample is acidified to a pH < 2 with concentrated nitric acid (HNO_3). The 0.5L polyethylene container is also acidified to a pH < 2 but with concentrated sulfuric acid (H_2SO_4). Acidification is tested by universal indicator paper. Each sample is labelled immediately after treatment and placed into an ice packed refrigerator, and stored at 4^o C in the laboratory. Flow rate and water temperatures are taken on site. The analyses of water samples were conducted in accordance to standard practice [APHA-AWWA- WPCF 1989]. .

The field sampling results of a number of mines from the Illawarra region are summarised in Table 1 and numbers denoted to mines for confidentiality reasons.

WATER MANAGEMENT PRACTICES

Any water quality assessment program should identify the current water management practices of the mines. It has been found that these vary quite significantly from one mine to the other. Some mines rely on town water, others from dam and other mine drainage waters while others use recycled water both from process water as well as from the storm water runoff.

The type of mining processes such as washeries, dust suppression etc. produces effluent which need to be treated before disposal. The storm water quality and quantity also need to be managed at the site.

Discharge Standards

Under current legislation mine discharge water is grouped as being either site releases or discharges [McCotter, 1984]. The latter are defined as the loss of water from a site by deliberate human or mechanical intervention such as pumping or the opening of valves. Licences for discharges vary from colliery to colliery depending on the classification of their local waters but generally speaking the discharge limit are as follows:

Chemical Oxygen Demand (COD)	≤ 30 mg/L
Non-Filterable Residue (NFR)	
non sensitive area	≤ 50 mg/L
sensitive area	≤ 30 mg/L
pH	6.5 - 8.5

Pit waters are normally controlled by pumping and limits are frequently placed on their direct discharge into receiving waters. Where possible, collieries are encouraged to recycle pit water for dust suppression, washery make up, and other on-site uses. [Loveday, Atkins and Aziz 1984]. Site releases refer to the loss of water from a site by the overflowing of dams and other control structures during storm events. As they are caused by natural weather conditions, it is not deemed feasible to license the actual water release. Instead, satisfactory water quality is achieved through the placing of performance specifications on the necessary control works. This is achieved by the procedure outlined in the Clean Waters Act 1970 [EPA 1970]. Runoff from haul roads and unrehabilitated overburdened areas is governed by these provisions.

Water Quality Parameters

The various water quality parameters for each mine were investigated at three locations. It is found that most mining effluent discharges have a noticeable impact on the receiving water body. Detailed discussion on the water quality of individual mines is reported by Morton (1991).

Table 1 summarises the water quality parameters of the mine effluent which is an average of three separate field trips. Despite the fact that the frequency and duration of the sampling is short the trends are clear. Since the sampling was essentially carried out during dry weather flows the values will be only representative for dry flow conditions. The conductivity, TDS and TSS of all mine effluent waters were found to be higher than the raw water sources indicating the accumulation of soluble ions which give rise to salinity. Most mine waters were found to be moderate to very saline and are similar to many other industrial discharges.

TABLE 1

Illawarra Mines Effluent Water Quality Parameters [Sivakumar, Singh., Morton, 1992]

Mines	i	ii	iii	iv	v	vi	vii	viii	ix
PARAMETER (Average)	S3	S2	S2	S2	S2	S2	S2	S3	S2
Temperature °C	13	21	10	14	12	13	14	16	18
Flowrate ls^{-1}	7.6	-	0.31	3.1	0.09	0.68	3.75	7.60	-
pH	8.65	6.99	8.06	8.64	9.05	7.76	8.28	8.05	7.60
Conductivity ($mScm^{-1}$)	1,802	14,445	992	1,254	1,039	669	2,040	605	771
NFR (mg/L)	12	32	2	82	73	4	5	2	3
COD (mg/L)	33	58	14	61	106	17	13	9	10
Apparent Colour	247	43	30	548	640	48	48	45	1
Turbidity (NTU	25	18	5	30	49	8	10	5	1
Total Alkalinity (mg/L $CaCO_3$)	1,110	628	449	481	294	176	1,136	272	355
Sulphate (mg/L)	7.13	32.4	6.55	17.51	29.03	30.7	41.9	5.3	3.6
Iron (mg/L)	1.30	2.59	0.54	5.65	2.54	2.32	1.33	0.92	0.84
Manganese (mg/L)	0.24	0.31	0.16	0.20	0. 30	0.50	0.47	0.35	0.50
Potassium (mg/L)	4.54	28.27	4.01	3.16	6.71	3.58	5.70	3.53	4.21
Aluminium (mg/L)	3.28	5.32	5.0	9.22	10.88	5.4	9.64	6.98	7.37
Calcium (mg/L)	20.03	87.05	39.88	18.72	25.75	45.25	29.61	36.57	82.0
Magnesium (mg/L)	18.53	935	24.32	11.16	9.47	10.54	37.84	33.25	61.6
Sodium (mg/L)	151.2	148	141.8	151.18	146.3	108.2	152.3	83.2	61.7
Total Hardness (mg/L $CaCO_3$)	126	5,203	200	93	104	56	230	336	458
TDS (mg/L)	1115	8939	614	776	643	414	1250	375	477
TSS (mg/L)	1172	9389	645	815	675	435	1436	394	501

The alkalinities of the effluents were found to be high whereas acidity was not a problem. For example Mine (vii) has the highest alkalinity, sulphate and sodium levels. The effluent water from this mine is of sodium carbonate type and is characteristic of contamination from waters from deep sedimentary rocks.

The iron levels of the effluent seem variable. However the iron content of the Mine (vii) effluent is too high and will give rise to discolouration of the receiving water and may destroy the food chain to other aquatic organisms. The Mines (i), (iv) and (v)have particular problems with NFR, COD, pH, colour, turbidity and aluminium levels.

The level of NFR of all the mine effluence is shown in Table 1. Although the Mines (ii), (iv) and (v) effluent quality seem to exceed their discharge standards the results should be interpreted with caution. These results are based on limited data and detailed studies on the variability of these parameters due to weather conditions, mine operating practices etc. are necessary for further interpretation.

Table 1 also shows the level of COD in mine effluents in the Illawarra Region. Mines A, (ii), (iv) and (v) have exceeded the water quality limits in terms of COD requirements. The pH of mine water discharge in Collieries in Illawarra region indicates that in three mines the mine water is alkaline. Water quality in mines (i), (ii) and (iii) have exceeded the limit stipulated by EPA.

The overall assessment of mine effluent quality is under investigation. It was found that the quality of effluent from the Illawarra mines for pH, COD, NFR (sensitive) and NFR (insensitive) have exceeded by 33%, 44%, 33% and 22% respectively. During extended wet weather these values may be expected to be lower due to dilution effects.

CASE STUDY : WASTE WATER PROBLEM OF INCREASING pH AT MINE "(v)"

The mine site is situated on the Illawarra plateau approximately 50 kilometres west of Wollongong. The area is predominantly rural but is adjacent to several areas of low density rural housing.

The site is drained by two surface drainage networks with catchment areas approximately 200 and 250 hectares. This drainage system meets down at the bottom of the site above a filter lagoon. The water is discharged from the filter lagoon and forms a creek. Approximately 150m downstream, the creek joins up with the natural water course which during dry weather conditions does not flow. The creek winds its way through a rural setting and finally enters a major inland and environmentally sensitive river. The creek and the river downstream is classified as class "P" - Protected Waters.

The sources of water pollution at the mine arise from mine operations (where water is pumped to the surface after being used at the longwall face for dust suppression, drilling etc), coal handling and storage areas and surface run-off from areas including the workshop and transport facilities. Most of the waste water generated is derived from the pit and it is this water which is of prime concern.

The mine concerned buys an average of 1026 kL/d of water from a local water authority and uses this water underground for its mining operations. The water then drains or is pumped to a common pit sump underground where it is pumped to the surface. At this stage the water has a high alkalinity, high conductivity and a pH of 8.0. The water is acid dosed with concentrated sulphuric acid to a pH of 6.9 prior to being held in a Mine water holding lagoon for 7 days. The mine water then flows over a weir (2m deep) and it is from here that the pH has been observed to increase.

The water drains down approximately 500m of concrete piping to where it enters one of two Filter Lagoons which consist of blast furnace slag, granulated slag, perforated pipes and sand. The pH of the water prior to entering the filter lagoon is 8.2 and as it leaves and discharges into the creek, the pH increases to 9.1.

The pH of the water in this system is controlled by $CO_2/HCO_3/CO_3$ equilibrium and the mine water is high in both total alkalinity and conductivity. When such complex waters are agitated or aerated, CO_2 is released to the atmosphere and increases the pH content of water. Additional pH increases across the filter lagoon may be due to the basic constituents of the filter media.

In accordance with the new discharge conditions which will be granted by the end of this year to the mine, the waste water discharged shall not be of a pH value of less than 6.5 or greater than 8.5. It is for this reason that the mine waste water treatment system will need to be improved to meet the new Environment Protection Authority's requirements. Possible improvements include the relocation of the acid dosing plant to the bottom of the treatment system and/or replacing the filter lagoon with sand.

Other discharge limit conditions for the mine include the following:

- the average flow-rate shall not shall exceed 400 kL/d
- the peak flow-rate of wastes shall not exceed 25 kL/minute
- the wastewater discharged shall not:

  (a) cause more than 20 mg/L of BOD,
  (b) contain more than 50mg/L NFR and
  (c) contain any visible grease and oil nor contain more than 10 mg/L of grease and oil.

APPLICATIONS OF EXECUTIVE INFORMATION SYSTEMS IN WASTE WATER MANAGEMENT

As the surroundings to the mining operations in the Illawarra region consists of very sensitive environments, it is of paramount importance to manage the effluent before being discharged. Initially there is a need to analyse and monitor quality of water from variour sources namely underground operations, surface mining operations (if any), processing plant and services. The quality of water used in all four facilities is different with regard to water quality. Consequently, the waste water from each source should be individually treated and the majority of the water should be recycled, processing the water is necessary to maintain water quality compliance for usage in the mining operations.

As most mines emanate water to the mine workings from surrounding stata surplus waste water may have to be discharged in surface streams. In these cases quality of the water should be improved by on-site treatment and the quality of discharge should meet the requirements outlined in the section concerning Water Management Practise.

Executive Information Systems (EIS) should be used to provide efficient effluent management systems for the control of the complete reticulation system. Figure 1 outlines a conceptual model for the control of water quality and water utilisation in a large mine.

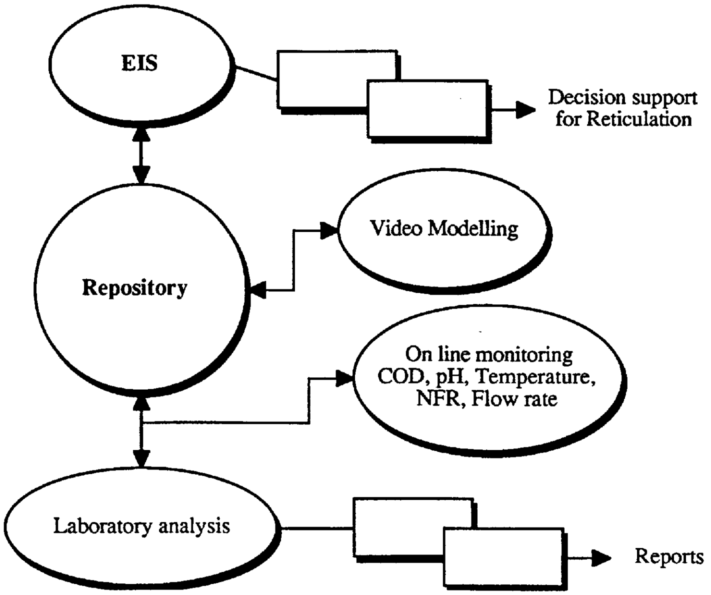

Figure 1 Conceptual Model Using Executive Information Systems (EIS) for the Control of Water Quality and Water Utilisation in a Large Mine.

The data is collated in the form of complete laboratory analysis of mine water from various parts of the operation which can be data entered via key boards, scanning or on-line systems. Monitoring on-line of mine effluent parameters such as, NFR, TDS, and pH can be easily applied because instrumentation and telemetry systems are readily available. These parameters can be monitored at salient points in the reticulation circuit, discharge points and also downstream of the outfall discharge. This information can be assessed via EIS systems to assist the control of the reticulation system of the mine.

This type of system may be used as an early warning for accidental releases or other malfunctions linked to the containment areas. Also the information obtained can be used to control site releases or discharges based on the receiving water quality such as storing and releasing at times when the dilution effect is high. In the situation of an arid site the surplus is normally stored in containment ponds during dry periods to minimize pollution of streams. Controlled discharge during high rainfall periods can be assisted by the use of EIS systems to give more information in decision support. In future it is anticipated that the complexity of the containment for discharge such as oil, grease, salinity, TDS, and some specific heavy metals from the mine effluent together with storm water discharge will require continuous monitoring and control.

CONCLUSIONS

Mine water can involve a range of problems in different mining conditions. Mine effluent water quality of the Illawarra region varies significantly from close to natural water to water similar in standard to industrial effluent. There is no hard and fast rule to combat local water problems in underground mining. The non-acidic mine effluent waters are considered to be caused by reactions of the varying amounts of carbonaceous rocks with the natural surface and ground water prior to their entries into the mines. These alkaline waters neutralize any acids formed by the reaction of water with pyrite. Some mine effluent waters had exceptionally high alkalinity levels. This became common for waters derived from particular types of sandstone, e.g. Scarborough Sandstone.

The primary water pollutant in Illawarra region is salinity. In 1990, 48% of mines exceeded the limit for COD (sensitive), 36% of mines exceeded the limit for pH and 20% exceeded the limit for NFR and continuous monitoring and treatment of mine water has improved the situation. Some mine effluent water have high alkalinity levels. This became common for waters derived from particular types of sandstone. This was particularly obvious at Mines (i), (iv) and (vii) where such pollutants as NFR, pH, COD, apparent colour, turbidity, iron and aluminium concentrations were found to be high during this limited study.

The limitations in this study include lack of data on seasonal variation as well as information on water quality parameters such as heavy metals, boron, oil and grease as well as chloride levels. Future studies should include these contaminants.

The use of EIS can collate information from a depository and would be useful in providing a more informative system for decision support in terms of quality control, treatment, recycle and discharge of the reticulation system.

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