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Mine Water Resource Management Systems

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ABSTRACT

The major operational objectives of a mine water resource management system (WRMS) are to supply the water needs of the mine and mill, to minimise disturbance to mining due to rainfall flooding or seepage and to dispose of excess water. Historically, company management have placed a significantly lower emphasis on managing the WRMS as compared to managing production. Changing Government legislation concerned with the disposal of water from mine sites is, in many cases making mining companies look more closely at how they manage their water. For example, within the next few years it is likely that prior to mining approval by the Government, mining operations will have to submit water management plans/budgets and contingency strategies in addition to operational plans. While the formulation of a comprehensive water management plan/budget is an additional cost to the company at the mine establishment stage, such plans can be beneficial to the operation in the longer term.

The two keys for the efficient design, operation and development of a WRMS are the establishment of written goals which have managerial priority and secondly, access to appropriate good quality data. Managerial priority towards the WRMS will increase as a consequence of the education of mine operators in the benefits to the operation of good WRMS management or less desirably as a requirement to meet Government legislation. The collection of appropriate WRMS data is a more complex issue and to obtain information efficiently and cost effectively relies on the clear definition of the data application.

Good quality data are usually expensive to collect. Unco-ordinated data collection will most probably lead to poor data quality, inappropriate data parameter collection or both. The four main time frames over which data would be applied in a typical mine are the design of the WRMS, the day to day operation of the system, the optimisation of the system, future planning, and the rehabilitation of the mine. The data applications are formulated from a knowledge of Government and mining/milling operational requirements. It is therefore obvious that immediate, short-term and long-term requirements need to be clearly specified. However, for expected long life mines it is difficult to predict requirements ten or more years into the future.

Mine WRMS are generally at their infancy in both development and understanding. A pro-active stance by mining companies to improve development and management of their WRMS will reduce the potential financial impacts of changing legislation and is likely to improve the overall efficiency of the mining operation.

INTRODUCTION

Mining companies have historically placed a significantly lower emphasis on managing mine water resources than on managing production. Changing government environmental legislation concerned with the disposal of water from mine sites, including seepage from water and tailings impoundments, is in many cases causing mining companies to look more closely at water resource management.

This paper describes the design and objectives of a mine water resource management system (WRMS), the current attitudes towards the WRMS and legislative trends. Suggestions are made for meeting the challenge of maintaining a cost effective industry within changing legislation.

THE MINE WATER RESOURCE MANAGEMENT SYSTEM

A mine WRMS comprises all systems and structures that are used to supply, manage and dispose of water associated with the mining and milling operation. These typically include:

1. water retention ponds,
2. sediment control structures,
3. supply pipes and pumps,
4. pit dewatering system,
5. storm drainage,
6. catchment bunding,
7. external water supplies such as municipal reservoirs or creeks, and
8. tailing dams.

A WRMS is specifically designed and unique to an individual mining operation. Design objectives include:

1. meeting mill and mine projected water demands, which may vary within the year and over the years,
2. supplying sufficient pit dewatering capacity,
3. operation within Government Environmental Guidelines, and
4. catering for final rehabilitation of the site.

Typically an iterative modelling process is used in designing the WRMS and is often based on calculation of retention ponds water balance:

$$\text{POND VOLUME}_{t+1} = \text{POND VOLUME}_t + \text{INPUTS}_t - \text{OUTPUTS}_t$$

where t represents the time step. Inputs include catchment rainfall/runoff, pit dewatering and transfers into the pond. Outputs include mill and mine water use, evaporation and seepage.

Additional water of varying quality may be sourced from local groundwater aquifers or from off site.

Models are approximations to actual systems and the model uncertainty is a measure of the expected error in the results. The uncertainty in the modelling results is a function of the accuracy of the individual water balance parameters, which may exceed 100 per cent in total. Each water balance parameter is estimated using site specific data, regional data and engineering experience. Some attempt is usually made to estimate parameter variability as an input to a model sensitivity analysis. In an audit of Ranger Uranium Mines' environmental impact statement document, Armstrong and Reid (1989) compared the predicted and actual performance of the WRMS and found that the actual annual water yield in year ten was less than 50 per cent of that predicted.

The most difficult parameter to estimate in the pond water balance is usually the catchment rainfall/runoff water yield. Firstly, rainfall cannot be predicted with any certainty. Annual rainfall is an independent random variable described for non-arid regions of Australia by a normal probability function (Pittock,

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1975) or by a Log Pearson function incorporating a skew parameter (Pilgrim, 1987). Within arid regions the annual rainfall may be fitted to a truncated normal or gamma probability functions. The appropriate probability function for the mine site is used to demonstrate annual exceedence probability (AEP) compliance, a component of some Government guidelines. (AEP is the average period between years in which a value is exceeded.)

Conversion of rainfall to runoff is achieved through derived rainfall/runoff relationships. These relationships may be fitted from site specific or regional data but are more commonly estimated by the engineer as data are usually limited. A modelling time step of one month is often used in a mine water balance as the rainfall/runoff relationship approaches a linear function with increasing time step and therefore reduces the complexity and uncertainty of the relationship (O'Conner, 1976). Time steps of a week (Franklin and Maidment, 1986) or an event (Bogardi, Duckstein and Rumambo, 1988) may be used where appropriate data are available to develop the rainfall/runoff relationship, however such situations are rare in mining environments.

In the translation of rainfall data from regional data to smaller basins, such as a mine site, errors of tens of per cent are not unusual (Clarke, 1982). This can seriously influence the reliability of rainfall/runoff simulations and design variables such as extreme flood (Burnash, 1983).

Surface water systems are vulnerable to the natural variability in climate. Too much rainfall may lead to flooding of the pit or unauthorised discharge from a retention pond; too little rainfall may result in an operation shutdown. Surface water systems' design is often an iterative process balancing company accepted risk of system failure. Recently, coal mines in Northern Queensland had to contend with the extremes of climate having to operate within a drought at the end of 1990 followed by flooding at the beginning of 1991 that resulted in downtime. It is understood that some mines incorporate downtime due to expected pit flooding into their mining schedules.

Risk is a concept that is well understood and accepted in exploration and financing mine development projects. However, a 'zero' risk is still demanded by some mining operations in respect of product production without being aware of the cost and technical requirements to provide a negligible risk water supply system. All mine WRMS are at risk of failure from design exceedence and human error. Risk can be determined when all possible future outcomes and their respective probabilities of occurrence are known or estimated from historical failure information. As a general rule a reduction in risk is proportional to an increase in engineering costs as shown in Figure 1.

In major Australian population centres water resources generally are taken for granted. A user expects to obtain the required volume of water by just turning on a tap. In the mining industry the attitude is similar the the management of mine WRMS generally has a low priority compared with production (McQuade and Gillies, 1992). This attitude is expected when water supply comfortably meets demand and where there is no limiting requirement on the disposal of excess water. In this situation water in excess to dust suppression within the mine is often 'intolerable'. It is variously treated as a loss of freedom of choice in the location of ore extraction, a cause of increased damage to rubber tyres or a detrimental effect on turn-around times. It may result in potentially unsafe working conditions which require a shift standdown.

Alternattively, where water supply is limiting due to quantity or quality the company often places a higher priority on the WRMS compared to production as mis-management of the WRMS could lead to lost production. Generally, company knowledge of how the WRMS works is poor with few companies able to provide a balanced annual water budget (McQuade and

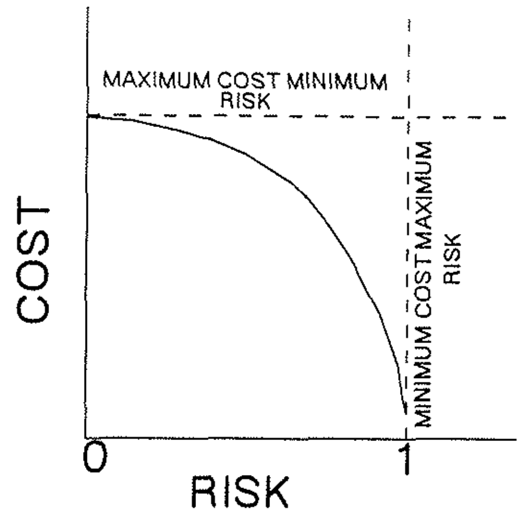

FIG 1 - Engineering cost vs risk of failure.

Gillies, 1992). The knowledge of how the system would react in times of extreme events (drought or flood) or runs of surplus or deficit is also limited. Few WRMS are performance reviewed during the history of operation, presumably due to adequate operational performance or limited availability of site specific data necessary for a review.

As mentioned in the previous paragraph, often minimal site specific data is collected to assess the performance of mine WRMS. The exception appears to be those companies that rely solely on groundwater reserves (McQuade and Gillies, 1992). These companies tend to collect 'drawdown' and 'volume pumped' information against time data for periodic review by specialist consultants. Cordery and Cloke (1991) reviewed the value of collecting streamflow data against the cost of building water resource systems. For a water storage facility of capital cost approximately $M17.6 they found the uncertainty cost was approximately $M4.2 with ten years of data and $M3.0 with 20 years of data. The cost of collection of data was estimated as $5000 per year.

Most new mining operations have only minimum opportunity prior to development to collect long-term water resources data. However, the collection of quality data during the operation is valuable for operation development, reducing the uncertainty in the design and therefore compliance with government guidelines, as well as providing data necessary for rehabilitation. Throughout Australia the collection of additional rainfall and stremflow data by mining companies could form a valuable asset for future mineral development projects.

Legislation impacting on the mine WRMS has generally not limited the management of mine water or its disposal in the past. Exceptions have occurred where disposal may impact on water resource users down stream of the mining operation (usually covered by a State Control of Waters Act) or where the potential pollutants are emotionally sensitive such as in the case of uranium mining or cyanide tailings from gold mining.

Rehabilitation techniques, which include water management, applied to bauxite mines in Western Australia are reviewed annually with the Department of Conservation and Land Management (Koch and Kaeding, 1989). Since the commencement of operation Ranger Uranium Mines in the Northern Territory has been required to submit six-monthly water management operational reports to the Department of Mines and Energy for assessment and compliance review.

LEGISLATION TRENDS

The growing environmental concerns of the public expressed through environmental legislation are having an increasing impact upon the minerals industry. Most mining companies now need to consider noise, radiation, dust, fibres, clean air, clean water (surface and/or ground), clean soil, site aesthetics, archaeological sites, wetlands, endangered species and even the possibility of climate change in the development of a mining operation. To meet the conditions stipulated within the legislation, mining companies are having to increase their administrative, capital and technical resources with corresponding increases in production costs.

The mine WRMS is usually a main component of environmentally oriented legislation as surface and ground water are major pathways for potential contaminants to travel off site. Legislation modifications in all states and territories have several common trends.

1. The principle of best available technology economically achievable (with the incorporation of flexibility allowing for practical experience and development in technology) is being used to guide environmental management from design to rehabilitation stages.
2. Powers enabling government to fine companies significant sums of money for infringements of environmental guidelines. Fines may be lodged against the operator, the company or even individual company board members.
3. The requirement for lodging Unconditional Performance Bonds and/or Rehabilitation Bonds.

In Western Australia the quality of discharge water is legislated under the Environmental Protection Act (1986). Specific requirements for the individual company are incorporated in the Conditions of Licence. Examples of such conditions taken from two licences are:

1. All matter containing saline, alkaline or cyanide constituents shall be retained within impervious holding facilities, such that there is no discernible impairment to surface or underground waters.
2. If, in the opinion of the Water Authority, the project has caused or threatens to cause any significant impairment of the quality of surface or underground waters, the licensee shall take appropriate measures to restore the quality of those waters to a condition similar to that prevailing prior to establishment of the project.

Queensland has introduced 'receiving water' criteria for users of cyanide and the Northern Territory has passed (but not yet promulgated) a new Mining Act with significant powers over the disposal of water.

Government resources to design and implement environmental legislative changes are limited, consequently guidelines for managing mine WRMS in the area of water disposal tend to be conservative. For example, in Western Australia all tailings dams must have seepage collectors installed. Companies are encouraged to allocate resources to research and collection of appropriate data and may use these data to technically justify a less conservative approach for the individual operation.

In the past site rehabilitation has generally not been a complex task and often not considered necessary at all. However, governments are now requiring mining companies to rehabilitate sites to agreed standards incorporating components of water management to meet water quality, erosion control or vegetation growth goals.

Active environmental management incorporating the WRMS is no longer an option but an enforced necessity.

MEETING THE CHALLENGE

The cost effective introduction of environmental guidelines into the mining industry will require a joint effort from government and the mining industry.

Governments can ease the burden on the mining company in a number of ways:

1. Parallel legislation or guidelines between States should be encouraged, thereby reducing the administration complexity for mining companies operating in several states.
2. Appointment of a single Department with appropriate resources through which mining companies would make all necessary applications and undertake any reporting, from the exploration stage through to rehabilitation of the mine site.
3. Guidelines for applications and reporting would provide clear standards for requirements. (The Department of Resource Industries, Queensland, has prepared planning documents to aid mining companies assess their operations for compliance to environmental responsibilities under the Mineral Resources Act (1989).)

Company policy and operational goals which lead to a positive attitude towards water management aspects as well as to production at the operating level are tools available for cost effectively incorporating new and future legislation changes into the day-to-day mining operation. Success in mining should be measured not only in technical and economic terms but also by environmental achievements. The successful application of these policies may be implemented through education of industry employees leading to greater care in the day to day tasks at the mine face. Education at the management level will broaden the information base for the decision makers.

This approach is being recognised as an important step by the Environmental Committee of the Australian Mining Industry Council which sponsors specific conferences and workshops to address environmental policy and education. It is up to the industry to provide direction to its representatives.

Education at the mine planning level is very important. Environmental guidelines affecting water management are now a necessary additional parameter for the mine planning team. Care in placing ore, sizing catchments, progressive rehabilitation and catering for flexibility in the pit operation can significantly reduce the impact of the vagaries of climate on the WRMS.

At the design stage it is important to consider how the site will be rehabilitated and water management requirements necessary to meet the rehabilitation standards. Progressive rehabilitation may also improve runoff water quality or reduce the size of controlled catchments which input water to the WRMS, both of which are beneficial to managing mine site water.

Increased environmental control will represent an expense to the company at all stages of mining from construction to rehabilitation. To minimise the financial impact companies need to invest in the collection of key data and applied research.

Data collection and applied research will provide the tools necessary to improve the flexibility of the operation and reduce the risk of failure of the mine WRMS. The design of a data collection program must begin with well defined and supported goals. The data collected will then form a valuable resource to the company and to industry. Collecting WRMS to satisfy government requirements does not always result in quality data that can be used for system planning. Figure 2 depicts monthly water flow data from two sources into a storage tank feeding a mill. It can be seen that significant errors can occur in relatively simple data monitoring.

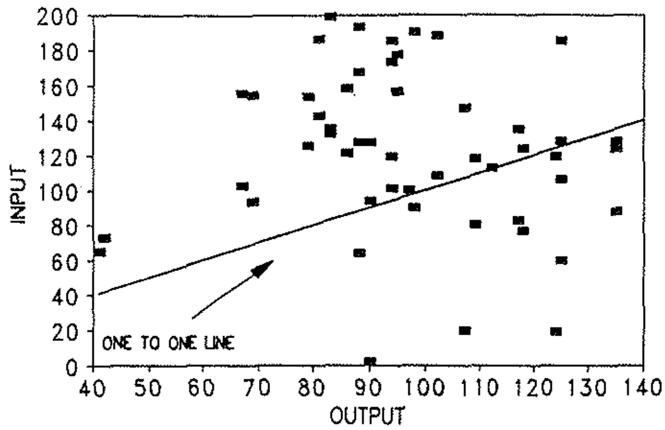

FIG 2 - Storage tank input vs output.

The following list of WRMS data collection goals represents different needs and each may require a different collection system or time step.

1. Provide data to size water supply ponds to meet the needs of the mine and mill and operate within environmental guidelines.
2. Provide baseline data for future environmental impact auditing.
3. Provide data for operational supply and demand forecasts;
4. Provide data to demonstrate compliance with environmental guidelines.
5. Provide data to technically justify a reduction in safety factors placed upon the operation.
6. Provide data for use in rehabilitation design.

The collection of data has traditionally been considered onerous and expensive due to the resources required. With modern electronic data systems this is no longer the situation. Australian designed and manufactured systems are now available to collect a variety of data and facilitate the transfer of the data into computer based storage. HYDSYS (1989) is an Australian water resources data storage system (marketed by a company of the same name) that has many facilities for data manipulation and interpretation. Such systems can be added to or modified to suit specific needs of companies. Consultants can prepare computer programs for the individual needs of mining companies which include data checking and data analysis.

A starting point for the justification of research is a cost benefit analysis. Tools need to be developed to quantify the WRMS cost to the operation of imposed environmental legislation as well as the cost of system failure in various scenarios. In addition, techniques are required to quantify the chance or risk of failure. The cost and risk information can be used to justify and prioritise research efforts.

CONCLUSIONS

The mining industry is now expending increasing resources to meet the requirements of broadening environmental legislation. This legislation is having and will continue to have a significant impact on the mine WRMS as water is a major pathway for potential pollutants to leave the site. The cost effectiveness of legislation needs to be approached jointly by government and mining companies. It is possible to reduce its impact on the operational costs of the company through careful preliminary designs, education, targeted data collection and research.

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