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An investigation into the impact of mine closure and its associated cost on life of mine planning and resource recovery

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ABSTRACT

Best practise environmental and social processes for mine closure at the time of decommissioning are well documented; however mine closure is often not given the recognition that it warrants during early mine planning phases. While it is recognised that mine closure and its associated costs need to be fully incorporated into the life of mine planning process, it is often not to the extent that it should be. This paper seeks to quantify the value that may be lost if closure planning is not adequately considered in life of mine planning and the difference in the mine plan between scenarios that adequately consider closure costs and those that do not. To demonstrate this, a case study is introduced for the purpose of investigating the effect of mine closure on various aspects of the mine design of a two dimensional copper deposit. Results indicate that mining operations may benefit from an altered mine plan whereby mine life is extended due to the time value of money aspect associated with closure. In addition to increasing the Net Present Value (NPV), the other significant finding is that this may also significantly improve resource recovery for minimal additional environmental disruption. It is demonstrated that mine closure needs to be incorporated as part of the optimal mine planning process from the very outset. It is also suggested that orebody characteristics such as size, shape, grade and dip are key variables in the closure cost/mine plan relationship. Mine closure and its associated costs need to be incorporated into the mine planning process to thus play a significant role in determining the ultimate pit limit, pushback design, production schedule, mine life, resource recovery and ultimately the profitability and NPV of an operation.

1. Introduction

The term 'Mine Closure' is most commonly associated with the environmental remediation of a depleted mine site and the decommissioning of associated process facilitates and other infrastructure. Mine closure costs are an inevitable expense that must be incurred once an operation commences; both during, and after the exploitation of an orebody. Closure costs are often not given the recognition that they warrant as part of the holistic mine planning process. This may be because these costs are mostly incurred at, or toward the end of the mine life and the view is thus often taken that these will be dealt with once closure approaches, or alternatively, the operation is sold in an attempt to divest responsibly for closure. However, as this paper demonstrates the impact of mine closure can have a very significant and profound impact on the optimal mine plan and therefore needs to be fully incorporated into the mine planning process from the very outset.

Companies today operate against a backdrop of increasing public scrutiny over environmental impacts and community relations. Mine closure aspects will therefore continue to become increasingly important. The reality is that as ore grades decline, more ore needs to be mined and processed at lower grades just to keep producing the same quantity of metal. Amongst other things this results in a higher volume of waste rock being generated, more land being distributed and higher greenhouse gas emissions (Topp et al., 2008). This in turn places greater social pressures on new and existing mining operations (Mudd, 2007). While best practise environmental and social processes for mine closure are well documented, academic literature that seeks to quantify this in terms of changes to the mine plan and its associated value is lacking.

The closure stage is the final phase of the mining life cycle which involves decommissioning, rehabilitation, reclamation and post-

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closure monitoring and maintenance. Mine closure is not only affected by the mineral resource but also economic, geological, geotechnical, regulatory, community and other factors that contribute to a sustainable decommissioning process (Laurence, 2006). Sustainable mining practises need to be technically appropriate, environmentally sound, financially feasible and socially responsible right through to mine closure (Department of Industry, Tourism and Resources, 2006). Planning for the closure of a mining operation should be carried out as part of the due diligence and feasibility study process. In practice however, adequate closure plans are often not completed in the early phases of planning. As a result of this, the true cost incurred of carrying out closure is not fully incorporated. In order to be feasible, mine closure costs must be accurately estimated ensuring that sufficient funding is available when it comes time to decommission and closing an operation. When carried out properly, the incorporation of closure costs into the strategic mine planning process plays a significant role in generating the mine plan and its final design. Mine planners still face the challenge of accurately incorporating the true cost of closure into the iterative mine planning and cost estimation process.

Optimising the timing of the closure cost spend over the mining cycle may result in improved financial outcomes. In planning resource projects, mine planners seek to improve value by striving to delay costs which are usually associated with the removal of waste and overburden material and/or by bringing forward the revenue associated with the sale of the valuable mineral.

This paper aims to investigate how mine closure cost and the timing of when it is incurred, may alter the mine plan. More specifically this paper assesses the impact of closure cost on the ultimate pit limit (UPL), pushback design, the production schedule, mine life, resource recovery and finally the value of the deposit being exploited and how these may change across a range of closure costs. An open pit mine case study is introduced to investigate changes to the optimal mine plan across a range of closure costs. Traditional approaches to accounting for closure costs will be compared to a new fully integrated approach.

2. Background

Mining operations are normally closed when the reserves they are exploiting have been exhausted under present commodity price conditions. The basis for determining if material within a resource is feasible to exploit as part of a mine plan will depend on economic factors whereby the value gained from selling the valuable product exceeds the cost of mining and processing it (Lane, 1988). Ideally, mine closure will always be an activity that is executed according to the mine plan. However, due to the volatile nature of commodity prices and other factors, many mines are forced to close prematurely. Laurence (2006) points out that up to 70 percent of mine site closures in Australia in the 25 years up to 2005 were actually unplanned as a result of factors including low commodity prices, high operating costs, lower reserves and adverse geotechnical conditions. Dowd (2005) highlights the significant cost associated with unplanned closure by finding that unplanned closure can cost up to five times as much as an orderly planned closure process. While the impacts of unplanned closure can be severe, this paper focuses on the planned closure process.

2.1. Implications of mining and mine closure

The negative environmental, social and economic impacts associated with mining activities which are generally magnified or become more apparent after closure are extensively discussed by numerous authors including Worrall et al. (2009), Bridge (2004), Hilson (2000) and Kenrick (2012). Some suggestions for managing these impacts are provided by Giurco and Petrie (2007) (Kemp et al., 2010) and the Department of Resources, Energy and Tourism (2015). Too often mining companies have taken a short term view without considering the longer term implications of mine closure. The potential effect of opening a new mine or simply changing the mine plan of an existing operation may cause serious environmental impacts on surrounding landscape and water systems including, chronic soil erosion, heavy metals overloading and acid mine drainage which can leave a lasting legacy (Hilson and Nayee, 2002). In most western jurisdictions mining companies are required to conduct environmental monitoring; not just at the time of closure but in some cases this may be required for many years after closure (Vintró et al., 2014). The challenge for mining companies and society as a whole is to ensure quality living standards now by being able to produce the metals needed in everyday life at a reasonable cost while protecting the environment for future generations (Azapagic, 2004). There is a trade-off between what society is prepared to pay for the commodities and the resources that maintain our current standards of living and the extent to which the environment may be harmed as a result of this. For the purposes of this investigation, the focus will remain on the cost of carrying out all closure related issues. This should include all costs associated with the environmental, social and community aspects of mine closure. The detailed daily workings and technicalities associated with environmental, social and community activities required to achieving a sustainable operation and ultimate closure are beyond the scope of this investigation.

2.2. The bond guarantee

In many countries mining authorities require the receipt of a bond payment before development works on the exploitation of a mineral deposit can begin (Gerard, 2000). The purpose of this bond is to ensure that funds are in place to carry out rehabilitation and remedial works by the relevant authority in the event that the company becomes insolvent. While there are various formats, the size of the bond payment is usually calculated as a percentage of the estimated cost to complete remedial works once closure takes place. Mining companies will need to provide additional funds to carry out remedial works associated with closure as the bond payment will not usually cover the full expense of this. Under normal circumstances the bond may be released to the mining company until such time that it is required as part of the environmental works associated with closure (Gerard and Wilson, 2009). The size of this bond will vary across different jurisdictions, however in many cases this will number into the tens and in some case hundreds of millions of dollars. In addition to the extensive and time consuming environmental impact studies that are required across most developed economies when proposing a new mining operation, the bond payment is often a substantial percentage of the overall capital cost associated with the development of a mineral deposit. Even so, the size and effectiveness of the bond payment system has often been questioned. Kahn et al. (2001) propose a newly developed bond system which provides economic incentives and has been proven to contain effective environmental policy in mine closure and planning within the Brazilian context. While it is seen as a vital part to ensure sustainability, the bond payment system has also been partly responsible for excluding many smaller mining companies from ever being able to develop larger deposits.

The size, in combination with the upfront nature of the bond payment unfortunately works against the NPV concept. All costs associated with the mining process are ultimately reflected in the final mine plan - from initial ultimate pit limits to sequencing and