In Pit Tailings Storage Facilities: Maximising the Benefits from the Investment: Effective Management of these Landforms for Effective Closure.

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Abstract

This paper will briefly describe the advent of the use of In pit tailings disposal techniques in Western Australia, and the expansion of the technology across Australia. The paper is based on the existing literature and the experience of the authors and who have worked with the very earliest (sometimes unapproved mid 1980), In pit TSF's, following these through to the closure and decommissioning, and thought to the closure works at many of the present day well designed and fully licensed facilities.

Traditionally early In pit tailings storage facilities were designed with no, or limited underdrainage systems to assist in consolidation prior to closure works, as a consequence some In pit TSF's were unconsolidated and therefore difficult to cover. Capping unconsolidated In pit TSF's to natural surface with waste rock material can be a expensive and complex process. Individual closure planning per In pit facility rather than a "one approach fits all" style of response is required to effectively manage the closure planning at each facility.

Through a series of brief case study presentations, the significant opportunities, investments and closure decisions made at West Australian In pit TSF closures will be explored and studied discussed. In particular the closure of twelve In pit TSF's at Newmont Tanami /Granites minesites will be considered and the principles and learning's gained from these projects presented.

Introduction

Tailings disposal and rehabilitation in Australia has changed considerably over the past twenty five years (Jewell, 2005; Lacy and Barnes, 2006). There has been a gradual move away from the typical paddock style, multi-celled square shaped Tailings Storage Facility (TSF), constructed by the upstream method using tailings, to a variety of TSF's. The development of the Integrated Waste Landform (IWL) built with, or encapsulated by waste rock walls, are perhaps the most practical and elegant example of the concept of integration of mine waste streams - that has been recently applied to real world mining situations (Lacy and Lane, 2007). The use of Centrally Thickened Discharge (CTD) facilities, which brings the more recent and advancing thickened tailing and paste disposal technology into practice, has also advanced strongly (Jewel, 2005). However, clearly the most extensive major initiative has been the rapidly increased use of mined out areas (pits) for In pit disposal of tailings in Australia, East and West Africa; Lane (2008) lists fifty-five known In pit TSF's facilities. That list only represents only a portion of In pit TSF's, there are considerably more known to the authors around Australia.

In pit disposal of mine wastes is not a new phenomena, in that the more intractable waste have been moved into pits, particularly with stabilising historic Uranium Mill Tailings (Staub and Triegel, 1978) in the deserts of USA. Within Australia and around the world there is increasing use of these facilities, for managing difficult materials or in strategic planning, or opportunistic low cost disposal (International Atomic Energy Agency, 2000-2004). At the Ranger Mine, tailings from the No 1 pit were temporarily stored in a ring dyke impoundment; when the pit was exhausted and mining began in the second pit, tailings were then discharged directly into the exhausted No 1 pit. At the Nabarlek Mine, the entire ore-body was mined in a six month period and stockpiled for milling over the ten years, then the tailings were deposited directly into the mine pit. At Rabbit Lake Uranium Mine (Canada), tailings arising from mining and milling of the Collins Bay B-zone ore body are placed in the Rabbit Lake pit. At Seelingstadt, Germany, historic uranium tailings are deposited into mined out pits at Trunzig and Culmitzsch. At West Wits South Africa, cycloned tailings are discharged into an open pit after reprocessing for gold from the historic "Super Dumps" of South Africa.

History and Context for In pit disposal in WA: How did they start?

Its difficult to determine if the initial In pit TSF's were a strategic idea – by individuals within the Mining Industry, or if they were an accidental response to situations were tailing planning was ad-hoc and managers were forced to either temporarily suspended milling while they constructed Paddock TSF's, or decided to direct the tailings discharge lines to an exhausted pit. For instance literature reviewed during the planning for the closure of the Haveluck In pit storage facility in the mid 1990's, revealed that the storage was formally approved three years after it was brought into use due, to expedience in 1986 (Hillman 1989). Just 20 km south another mine decided to do the same, and deposited direct into the Bluebird pit, also thought to be without approval. At Haveluck, there was a dewatering effort through placing an underdrainage system in the pit floor. This underdrainage system failed, and a standard central decant system was put in place. The rate of rise in disposal to this particular facility was considerable, and subsequently ~7 years of consolidation was required before the site could be rehabilitated. A number of unconsolidated facilities In pit storage facilties created during the period 1986 - 2000 caused a great deal of consternation amongst the regulators during this early period. It was feared the sites would never consolidate, however most of these sites (apart from some that were filled level to the existing groundwater), appear to have been rehabilitated to a reasonable, acceptable and safe standard. Haveluck, one of the first In pit TSF's rehabilitated in WA, still appears to be successfully rehabilitated.

Expectations of Closure for In pit disposal in WA

Tailings Storage Facility closure is a process of closing down a TSF with the broad objective of leaving the facility safe, stable and non-polluting with little need for on-going maintenance. As stated in the **Strategic Framework for Tailings Management** (MCMPR and MC, 2003) there are a number of objectives that need to be considered when planning the final landform:

- Containing/encapsulating tailings to prevent leaching into ground and surface waters.
- Provide surface drainage and erosion protection to prevent surface water transporting tailings from the storage area.
- Providing a stabilised surface cover to prevent wind erosion.
- Designing the closure to minimise post-closure maintenance. (Lacy and Barnes, 2006).

The Dept. of Mines and Resources in W.A (1999) remind us that
"rehabilitation of TSF's must always be kept in mind when considering which tailings storage method is the most cost effective. Short term economic advantages of storing tailings in a mined-out open pit may be offset by very considerable monitoring and remediation works before rehabilitation can be done. Substantial rehabilitation costs may then be incurred once the pit is filled with material with, for example, a high liquid content and/or very low strength characteristics. Inpit tailings storage presents a number of difficulties not normally associated with the more conventional methods of tailings storage". DMP Appendix H (1999).

The DMP (1999) consider that TSF rehabilitation options available to a mine will largely be determined by the conditions in the top several metres of material in the TSF, and they would prefer that all TSFs were re-vegetated with natural plant species endemic to the general mine site location. The Guidelines provide a series of requirements in closing In pit TSF's. Geotechnical issues and a range of chemical and biological issues that may also need to be addressed to ensure viable lasting rehabilitation of In pit TSF's.

Closure at Newmont's Central Australian TSF's – Principals and Experiences

Justification

Recent options review process at Newmont indicate how important it is to consider the various justifications for In pit TSF's in an environment, particularly where operations are increasingly looking at fully or partially lined above ground facilities as a minimum corporate standard and commitment.

Biodiversity

The above ground TSF will necessitate the clearing of approximately nine times the size of the void footprint, often of undisturbed land. When the clearing takes place an established ecosystem will be removed which will often lead to the displacement and often demise of wildlife as the displace wildlife will be entering habitats already fully occupied by competitors. When the above ground facility is rehabilitated, it's biodiversity values will take many years to reach those approximating the pre disturbance area, if they ever do. Alternatively the use of abandoned voids as TSF's ultimately leads to moderate levels of biodiversity at the rehabilitated site, whereas currently abandoned open pits provide little of, and if left as such, never will.

Public Safety

A properly consolidated and closed In pit facilities is superior, to an open pit or above ground TSF combination, from the perspective of public safety. The open void is removed as a major risk, as apart from traversing the upper rehabilitated surface this style of landform provides limited opportunity for vehicle access or personal accidents or injuries.

Greenhouse Emissions

An accurate accounting between the total greenhouse footprints of the two TSF storage approaches would demonstrate a stark comparison. In addition to much more material to cover the closed facility, the above ground facility requires a large amount of energy to build the embankments and subsequent lifts, to pump the tailings to a higher elevation, to manufacture, transport and install plastic liners (when used), to install and operate seepage pumps which would be operating at a greater distance from the mine. In short, due to the these stark differences in total energy efficiency the above ground TSF option in comparison to In pit storage, will generate many more tonnes of greenhouse gas.

Stability

All landforms built by mining activities in arid Australia, if they operate to the best possible standards, will, over thousands of years, gradually re-integrate into the surrounding landscape. This inherently means that the rate of erosion, sediment loss and degradation is intended to be such that the surrounding environment can accept this planned degradation without significant impacts on biodiversity or other relevant values (groundwater, surface water, aesthetic etc). The realities are that the degradation of landforms is rarely predictable and the chance of failure due to variability in material or poor application of design or unforseen events of extreme magnitude within a given timeframe is high, with subsequent unknown impacts upon the surrounding ecosystem.

Stakeholder Preference

In some regions in which Newmont operates the Traditional Owners have made it clear that they would strongly prefer the pits generated through the mining process to be filled. This is not generally economically feasible as a stand alone activity but in the case of tailings as a backfill positive economics can be gleaned for the mine operator. The Traditional Owners support this endeavour preferring filled In pits, low profile or no “new landforms”. This preference can sometimes be accommodated through adopting the In pit option. Regulators have demonstrated consistently that they are willing to permit appropriately designed, managed and closed In pit Tailings Storage Facilities and have created no significant barriers in this approval and regulatory process.

Groundwater Quality

Groundwater impacts are most often the justification for not adopting in pit tailings storage and in some locations this is well justified and highly appropriate. In other locations the preservation of groundwater values where there are no known groundwater resources, and there is limited or no biological environmental use provides a low risk scenario for In pit disposal. The larger footprint of above ground facilities are likely to have considerably greater groundwater impacts, as the driving hydraulic head and the extent facility is much greater in comparison with In pit TSF, with more extensive and longer lasting groundwater impacts unless the facilities are lined.

Targeted seepage interception and dewatering systems considered in pit design, and during deposition can ultimately lead to a highly controlled and reduced impact on groundwater.

Surface water quality is of course much less likely to be impacted in the long term by an In pit facility versus an above ground facility, as the larger facility breaks down the facility and distributes this material into the surrounding surfaces.

Cost

Table 1 Illustrates recent estimates from a pre feasibility option assessment for TSF’s in arid Australia. They strongly suggest that the In pit was a far more cost competitive option, although the above ground option was recommended ostensibly for reasons of conformance to internal company standards.

Table 1. Prefeasibility Tailing Disposal Comparison – Arid Australian Tailing Disposal Costs

TSF Construction	***Construction Costs***	***Closure Costs***	***Resulting in Estimated Life of Mine Costs***
Option 1(Surface TSF) four stages embankment construction (lifts)	*$37 812 048*	*Option 1 - $7 622 200*	*Option 1 - $45 400 000*
Option 2 (in pit TSF)	*$1 647 321*	*Option 2 - $15 786 510*	*Option 2 - $17 450 000*

Where costs can become higher than anticipated with In pit TSF closure is during the closure process. Often assumptions about cover depth are simplistic and do not allow for consolidation issues or the need to marry the cover with the surrounding topography.

Closure Risk Associated with In Pit Tailings Storage

Context and understanding of the existing host environment

Clearly, an understanding of the hydrology and modelling of the likely migration of impacted waters is essential. It is essential is that realistic monitoring locations and groundwater quality thresholds are established at the outset. The practice of using old pit perimeter dewatering bores as monitoring bores and compliance points during the In pit operation should be avoided, as it is generally unrealistic to expect water quality to remain below monitoring thresholds in these close proximity locations.

Maximising Drainage Opportunities

Although the value of underdrainage can still be debated, given the long term risk and cost of consolidation and sink hole formation, it is recommended that it is carefully considered.

Operational Practice

This is generally where opportunities for good consolidation during tailing deposition and early closure preparation are missed. Give many mill operators a big hole in the ground and plenty of freeboard and you may quickly get “a new water storage facility” on site, or a situation where the water in the pit “isn’t good enough” for the plant, and subsequently little effort is put into recovery or dewatering. The latter justification has been observed in some cases to have been successfully used to the extent that there is no beach of any description on some facilities – a “In pit swamp scenario”. Of course the majority of operators take these matters more seriously, particularly if the consultancies or person’s who manage the site understand the growing implications of the “swamp scenario”.

Water Minimisation Strategies

Obviously the best method of water minimisation is to use it. Abstraction via underdrainage, perimeter bores if available and the formation of a water recovery location at the pond surface are the obvious initial choices. A filter wall of rock can be built and maintained to improve the quality of water recovered and provide more control to the recovery process.

If there is still difficulty in forming a beach, the approach of multiple spigots can be implemented. If there is still a positive water balance, there are actions operators can take rather than just give up on the dewatering challenge. One site instituted a site constructed “snow maker” which removed 4 litres per second from the pond.

It would not be difficult to generate a ring main around a pit perimeter and either spray or sprinkle the decant water down the outslopes of the void. This could dramatically enhance evaporation, particularly at certain times of the year or day, when evaporation is at its highest.

Drying and consolidation

One of the best approaches to drying and consolidation, if the production schedule allows, is to continue to operate the facility on a campaign basis once the notional fill height has been almost reached. This means that when the bulk of the deposition is going to the next facility in the strategy, the filled In pit TSF is topped up strategically from different locations to fill the void evenly and continue to charge the tailings. Care should be taken that absolutely all local drainage, including from the ramp, is directed away from the void. The use of above ground lifts – to support longer use of the facility – so that it can be sporadically topped up and allowed to dry and consolidate with only meteoric water as the main input, followed by the occasional period of deposition - the better for final landform consolidation and form.

Closure

With an material unconsolidated within a In pit facility - smaller earthmoving equipment will naturally be less likely to create breakthroughs and bow waves. Campaign closure of the surface can be an effective strategy as can placement type approaches, such as long reach diggers rather than dump and push methods. Naturally batter caving can be instigated if the facility has not been filled to the top of the pit, and is likely to be a satisfactory and cost effective closure option.

Drainage around the rehabilitated facility can be more complicated than was considered during the design process as sloped ground may create high walls which increase unavoidable catchment onto the rehabilitation surface. Local drainage may be diverted around or in some cases, over the rehabilitation surface, but consideration should be given to unforseen consolidation, as a result of allowing surface water ponding, or allowing spasmodic surface water flow across the rehabilitated TSF surface.

Monitoring

A great deal of resources can be expended on groundwater monitoring but consideration should be given as to what intervention is possible and what down gradient values are at risk of harm. The general likely extent of groundwater plums should be understood and monitoring should occur at the outer reaches of the expected plume. Monitoring of the plume near the pit perimeter is all too common, but often provides information of little strategic value if the plume front has passed this point. If there are no beneficial or environmental users and deposition has ceased, groundwater monitoring should be scaled down accordingly. Naturally, rehabilitation monitoring is applicable and consolidation should be part of basement during facility walking inspections annually (safety hazards may exist) due to consolidation, and care should be taken.

The consolidation performance cannot be absolutely guaranteed and provision should be made to monitor, and have the capacity to respond to maintenance and repairs for a reasonably and significant interval into the future. The primary risk is that of public safety, as these facilities are unlikely to be bunded.

In Summary

Careful consideration needs to be given to the relative impacts of In pit TSF's versus above ground style facilities, in use, during and post closure when making the decisions to select different tailing disposal options.

Design should responds to the groundwater hydrology, consolidation and post closure surface hydrology considerations. Active water management and consolidation enhancement should be part of the design. Expectations with regard to managing water quality changes and the likely extent and subsequent management of ground water mounds and or distinct plumes need to be realistic, a regulator environment that is appropriate for the situation , and that is monitored and reported appropriately is most important.

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