Critical Decisions for AMD Management

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Abstract

There are a number of critical decision moments that occur at a mine site that can dictate the ongoing Acid and Metalliferous Drainage (AMD) risk. In particular, the study phase of the mine development is the most important period to make decisions. It can be difficult and costly to reverse decisions or change AMD management strategies once the mine site has been developed, or AMD issues arise. This paper will present two case studies of critical decisions made that demonstrate the approach taken to set up the mine site for success in the management of AMD.

The first is a proposed copper ore mine that was in the study phase. Geochemical test work identified that most tailings would be classified as Potentially Acid Forming (PAF). The metallurgical processing scheme was subsequently developed to desulfurize the tailings and limit the high sulfur PAF tailings to 6% of the Tailings Storage Facility (TSF). The TSF design segregated the PAF material and limited oxidation through the use of a water cover. Thereby, since the majority of the tailings were now low sulfur tailings, the complexity, footprint, cost of capping at closure and the long-term management of the tailings were decreased. Consideration of the closure strategy early in the study led to a TSF design and closure cover system design optimised to reduce closure risk through the use of a dry cover that could maintain saturation of the high sulfur tailings. The critical decision to change the processing scheme and desulfurize the tailings was informed by early orebody definition and knowledge of the tailings properties gained ahead of mine commencement.

The second case study is a proposed iron ore mine that was in the study phase and demonstrates the use of a multiple option analysis to make knowledgeable decisions on the management of PAF waste rock and thereby limit the risk of AMD. The multiple option analysis was used to assess major hazards, planning, operational reliability and costs. Fatal flaws were identified, and feasible final landform options were developed for review by a multi-disciplinary team. Scores were weighted and the optimum strategy was identified. The multi option analysis enabled an informed decision to be made before mining of the PAF waste material occurred. It was a critical decision on how PAF waste material would be managed in the future at this mine site.

Keywords: Tailings, Fatal flaws, Decision analysis

Introduction

Acid and Metalliferous Drainage (AMD) is a long lasting, negative legacy at multiple mine sites. Many of these sites were developed before there was a good understanding of the risks to water quality from reactive mineral waste. A modern mine should be designed to prevent or significantly reduce both operational and long term risks from AMD (INAP 2022).

Water scarcity exists in some mining regions and there is considerable competition between mining and agriculture for water in a number of regions of the world. Conversely, mine sites in other regions may need to manage an excess of water. Hence avoiding negatively impacts on water quality (and quantity) is paramount.

Two case studies are presented that demonstrate how critical design decisions can set up the mine for success in the management or prevention of AMD. A case study is presented for tailings and another for waste rock, which are the two major mineral waste products that may generate AMD at mine sites. The case studies are specific to each particular location and deposit so the solutions may not necessarily be universally applied at other mine sites. However, some key messages are common to each case study:

- Early geochemical characterisation of waste materials to identify and quantify PAF materials will enable appropriate design decisions to be made
- Engaging multiple stakeholders is essential as there are often broader business considerations required for the solutions to be implemented successfully
- Re-evaluation of identified solutions is required as projects evolve and orebody knowledge increases

Case Study: Tailings Storage Facility (TSF)

Base Case

The project is a copper-gold deposit located in an arid region of Australia. Geochemical characterisation was undertaken throughout the study, informing the multiple changes to the processing scheme as the study progressed. It was found that all tailings would be Potentially Acid Forming (PAF).

Design Changes

To lower the AMD risk the following design modifications were made:

- Changes to the metallurgical processing scheme (desulfurization) were made to ensure the majority of the TSF contains Non Acid Forming (NAF) or low-capacity PAF tailings (AMIRA 2002). The processing scheme was developed to reduce the amount of sulfur within the low sulfur tailings and increase the amount of sulfur in the small amount of high sulfur tailings.
- A TSF design was made that allows segregation of PAF material within the TSF during operations.
- Storage of PAF tailings under a water cover were done during operations to limit any oxidation (figs. 1 and 2).
- Final cover design work was completed early in the study to ensure the high-sulfur tailings can maintain saturation at closure, with the installation of a suitable dry cover to encapsulate the deposited tailings and sustain vegetation over the long term (fig. 3).

The objective of the cover over the high sulfur tailings is to limit or prevent evapotranspiration and maintain saturation of the tailings, and thereby limit any oxidation. It should also be thick enough to limit capillary rise of salts that could impact vegetation establishment. Various cover design configurations were modelled to ensure the cover could function appropriately with the material types available and the given climate. Preliminary work has found that the cover thickness should be a minimum of 4 m and will need to consist of a coarser-textured (i.e. higher sand content) low sulfur tailings system with 0.5 m of metasediment near the surface for erosion control. This will likely decouple the saturated tailings from the evapotranspiration zone and maintain a high degree of saturation (>85%) in the high sulfur tailings. Both the low sulfur and high sulfur tailings cells will be lined.

Sulfur deportment to tailings was added in the mine plan and the result is a prediction of 6% high-sulfur tailings (with total sulfur concentrations > 25%) and 94% low-sulfur tailings (with an average total sulfur concentration of 0.2%). Low-sulfur tailings can still have some PAF material, but overall sulfur concentrations are low and there is a low capacity for acid generation in the long term, hence it is suitable for sub-aerial management.

Conclusions

Undertaking geochemical test work early (before mining) enabled the development of a metallurgical process scheme that aims to limit the high-risk PAF material to 6% of the tailings material.

If the geochemical test work had not been completed early in the study, then the majority of the tailings would have been considered PAF and been spread over the entire footprint of the TSF. This would have increased both the complexity and cost of capping at closure and the long-term management of material that had oxidised.

Consideration of the closure strategy early in the study led to TSF and closure cover system designs that were optimised to reduce closure risk. The TSF design not only allows segregation of PAF material within the TSF during operations but also limits oxidation by maintaining a water cover.

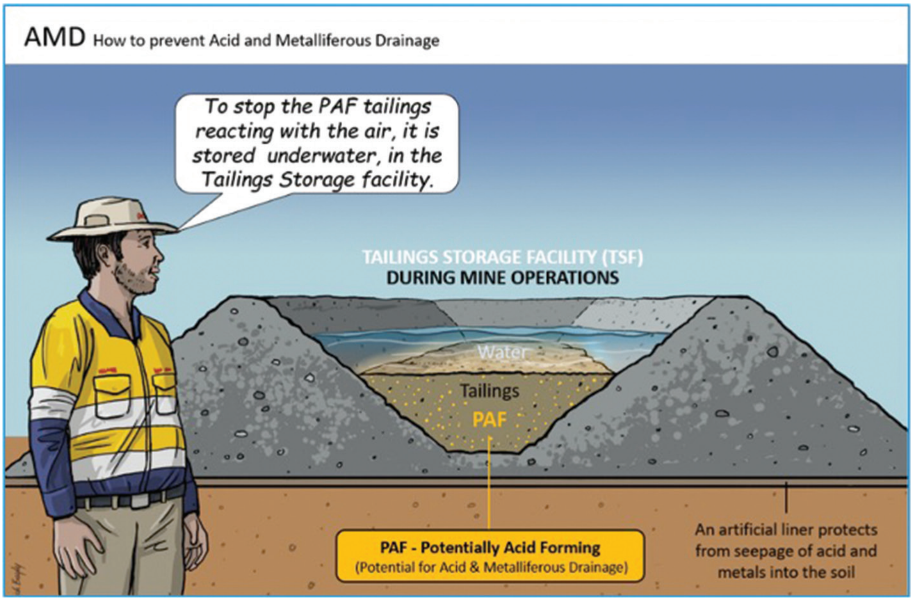

Figure 1 *Image of the high sulfur tailings cell.*

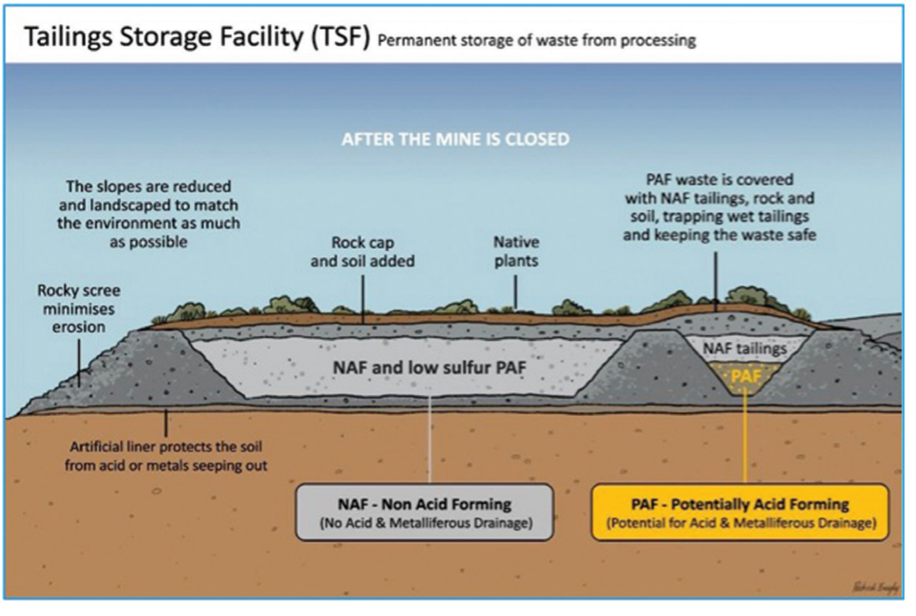

Figure 2 *Image of the TSF during mine operations.*

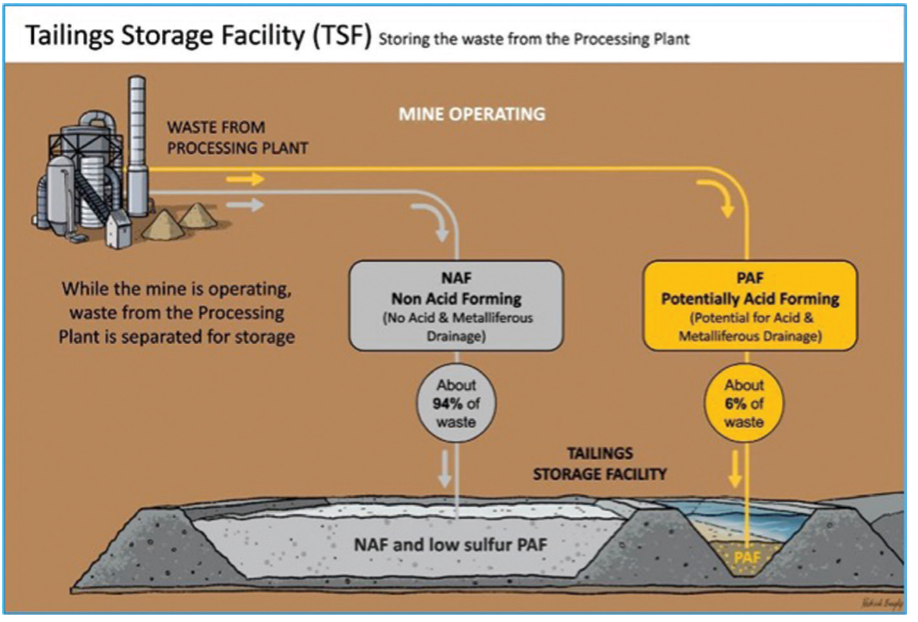

__Figure 3__ Image of the TSF at closure.

Case Study: Waste Rock Dump

Base Case

The project area is tropical, with a wet season (and 90% of rainfall) lasting from March to October, and a relatively high and uniform temperature with high humidity. Mean annual rainfall is 1,845 mm.

Whilst pH is naturally low in surrounding springs and groundwater, there is also a very low solute concentration i.e 8 μS/cm in springs and 130μS/cm in wells.

PAF material is determine by the sulfur concentrations, as there is a lack of neutralising capacity in the waste rock. In any given year the amount of PAF is expected to be less than 2.5% of the total waste, totalling 4.3 Mt.

The 2015 Pre-Feasibility Study (PFS) for this iron ore deposit segregated all PAF material in a separate waste dump. This material was to be placed onto a liner with seepage and runoff collected and treated through a treatment plant. This concept design was challenged as part of an update to the PFS during 2022 to determine if there was a more appropriate method to manage AMD in the short and long term.

Multiple Option Analysis

The process to evaluate design alternatives involved a series of workshops attended by multi-disciplinary stakeholders such as hydrogeology/hydrology, environment, geochemistry, mine planning, geology, project management, geotechnical engineering and operational readiness. Significant pre-work was undertaken prior to the workshop to develop predictions for contaminant loads and required treatment, as well as estimated operating and capital treatment costs. Closure considerations and capping requirements also fed into the assessment.

Assessment criteria were assigned a weighting based on discussions during the workshop on the importance to the project. Each assessment criterion was then scored by comparing the option to the base case. An example of the option analysis template that was used is illustrated within Table 1. A sensitivity analysis was also undertaken by adjusting weighting between groupings and determining the influence on the selection of a preferred strategy. Whilst alternate option selections varied, the preferred option was invariable and it was concluded that the selection process was robust in the identification of the preferred option.

Alternate Design

The preferred option that was selected minimises the footprint of the PAF material and therefore the volume of contact water that would be acidic. The PAF waste will be segregated and placed within a single cell, that is isolated within the central area of the waste rock dump (fig. 4). The cell will be away from the outer shell (not within the batter zone and removed far enough to limit oxygen supply) and would accommodate all PAF waste for the life of the facility. To achieve this, the PAF will be segregated at the mine face and placed selectively in the single cell in thin layers and compacted. On completion of the cell, a low permeability cover will be emplaced and an internal water shedding cover (with capillary break underdrain layers) will be constructed to minimise contact water. On completion, the PAF cell will be covered with 5 m of NAF material. Work is currently underway to provide design criteria for the mine plan and detailed waste rock dump design. Predictive modelling is also planned to determine if a treatment plant can be avoided altogether.

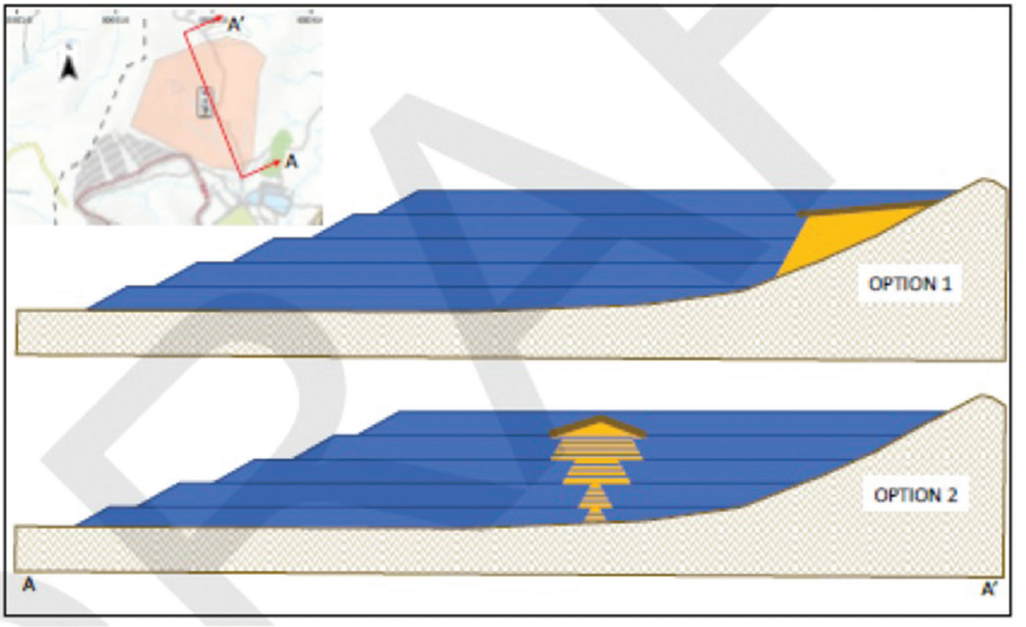

Figure 4 *Schematic illustrating placement of PAF material in thin layers in a single cell of fixed dimensions (Option C-1) and variable dimensions (Option C-2) to meet the PAF production schedule.*

Table 1 *Three of the options that were assessed during the multiple option analysis workshop.*

					Base Case		Option A		Option C	
					Segregate and permanently encapsulation in separate dump adjacent to northern dump		Co-deposition of PAF with NAF		Segregate and encapsulate in single cell	
Group Weighting		Assessment Criteria	Description	Individual Criteria Weighting	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
	Without a FATAL FLAW				Y		Y		Y	
50%	Major Hazard									
	H1	Acid generation risk	Will this option decrease the risk of Acid Generation?	3	4	12	1	3	3	9
	H2	Storage failure risk	Will this option result in the exposure or release of PAF	2	4	8	5	10	6	12
	H3	AMD collection risk	Will this option result in impacts to springs and ecosystems?	4	4	16	2	8	3	12
	H4	Closure risk/complexity	Will this design increase the closure complexity?	3	4	12	2	6	6	18
	H5	Proven technology	Has it been done before with success?	3	4	12	2	6	4	12
		Weighted Sub-Total		15		200		110		210
10%	Planning, Design a									
	P1	Minimise delay to the ap	Will this approach allow us to secure permits with less effort	1	4	4	1	1	5	5
	P2	Minimise impact to stakeholder existing	Will option minimise impact to the existing stakeholder	3	4	12	1	3	4	12
	P3	Maximize resilience to changes in PAF	Is the option flexible enough to cater for future increases in	3	4	12	7	21	5	15
	P4	Maximize ability to identify and control	How easy it would be to ensure the option will appropriately	3	4	12	7	21	4	12
	P5	Land disturbance	Will the disturbance footprint increase?	2	4	8	6	12	6	12
		Weighted Sub-Total		12		40		48		47
20%	Operability/Reliabi									
	O1	Implementation - PAF n	Will this option require less effort to be implemented?	3	4	12	7	21	3	9
	O2	Implementation - water (	Will this option require less effort to be implemented?	3	4	12	1	3	2	6
	O3	Performance - PAF mar	Will this option result in a better performance to mitigate AMD	3	4	12	1	3	6	18
	O4	Performance - water ma	Will this option result in a better performance to capture and	3	4	12	1	3	3	9
		Weighted Sub-Total		12		80		50		70
20%	Cost									
	C1	Construction Cost - site preparation and	Will this design provide cost saving for construction?	2	4	8	6	12	6	12
	C2	Operational Cost - ongoing operational	Will this design provide less operational cost?	1	4	4	6	6	3	3
	C3	Water treatment - Capital costs		3	4	12	1	3	7	21
	C4	Water treatment - Operational costs		4	4	16	5	20	7	28
	C5	Closure		2	4	8	1	2	5	10
		Weighted Sub-Total		12		80		72		123
100%		Weighted Grand Total		51		400		280		450
		Ranking			3		5		1	

Conclusions

The waste rock dump design for PAF material that was developed during the 2015 PFS was challenged to determine better alternatives. The option analysis workshops enabled a PAF storage option to be carried forward in the study that:

- Is more protective of the environment
- Considers mine closure and long term AMD risk
- Offers cost savings from the operating and capital perspective.

The multi criteria analysis workshops enabled a collaborative approach that considered broader study and site perspectives and enabled 'buy-in' by stakeholders.

References

AMIRA International (2002) ARD Test Handbook, Project P387A: Prediction and Kinetic Control of Acid Mine Drainage. Ian Wark Institute: Adelaide

INAP (2022) Global Acid Rock Drainage Guide. www.gardguide.com