

# Developing the Business Case for Responsible Acid and Metalliferous Drainage (AMD) Management

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## Abstract

Despite advances on AMD solutions and greater understanding of management options, barriers remain to their implementation. The CRC TiME therefore asked a diverse group of stakeholders, what was the root cause of the failure to implement AMD solutions. The stakeholders identified ten themes that spanned across organisational practices, cultural behaviour, engagement and communication, current business models, decision-making tools, and scientific understanding. Together, these can cascade into ineffective management of AMD throughout the life of mine and closure. This work highlights the need for action on aspects that are non-technological and could have a deep impact on planning for closure.

**Keywords:** Acid and Metalliferous Drainage, Organisational Culture, Organisational Change, Stakeholder Engagement

## Introduction

Mining is a crucial sector for human and economic development with an unprecedented growth, expected to double in the next fifty years (OECD, 2019). However, the positive contributions of the mining industry to global development, frequently come with environmental and social costs when mining activities trigger the formation of acid and metalliferous drainage (AMD). The lack of timely management combined with the challenges of waste containment, have caused environmental impacts with long-lasting, irreversible perturbations in ecosystems as well as on the economic and social fabric of local communities.

AMD environmental and socio-economic impacts have stimulated the strategic development of targeted prevention and remediation solutions. Nevertheless, developing a universal technical solution for AMD has proven difficult due to the lag time for its impacts to manifest, the variation in site geochemical characteristics, mining methods, hydrological and climatic conditions, (Thisani *et al.*, 2021). Whilst treatment solutions offer high efficiency and

reliability to achieve statutory compliance, they have become increasingly sophisticated and expensive due to the associated technology, energy, capital and maintenance costs. Delayed implementation of proactive AMD management from the early stages of a mine project, combined with “end-of pipe” solutions, result in increased management costs at closure stage. Despite regulatory compliance, adherence to permit conditions and the development of risk management plans, some projects can still result in significant environmental, social and economic impacts in the long run. Operational management focussed on source control processes and improved analytical prediction tools, together with risk assessment frameworks, have been vital to decreasing AMD risks and liabilities. Nevertheless, despite advances in risk assessment tools, there is still a perception that management of AMD risk is not a key driver of mining operational priorities and decision-making, resulting in failures to manage AMD adequately, and in the continual creation of mine closure liabilities (Commonwealth of Australia, 2019).

Failure in AMD management results from a complex interplay between environmental, social-economic, cultural and historical contexts, coupled with corporate practices and norms that typically don't embrace methods suitable to tackle such challenges. In addition, dynamic societal attitudes, stakeholder expectations and regulatory policies, together with a drive to better understand community values and aspirations, means governance of mines is increasingly challenging, and enhanced strategies for decision-making are required. In this context, AMD management can be seen as a classic example of a *wicked problem*, where dynamic and complex situations arise, involving stakeholders with different value systems. A wicked problem is often a symptom of a deeper underlying problem. However, the interrelationship between the different aspects makes understanding the deeper problem difficult and uncertain. Consequently, assessing potential solution(s) and achieving a shared understanding of the problem can only be done by considering a complete range of experiences and involving all perspectives. A well-established approach to this challenge is through participatory dialogue with diverse stakeholders in a collaborative analysis, to discuss "the problem", and unveil explicit and tacit knowledge to establish a common understanding of the root cause(s) for AMD intractability.

## Methods

This project utilised a participatory dialogue approach engaging with a multidisciplinary and internationally diverse AMD stakeholder group, to assess the issues surrounding AMD, the opportunities for improvement, and to support the refinement of the business model for improved AMD management. A process called Open Space Technology (OST) was used for the participatory workshops, which were run under the theme "AMD intractability". During the workshops, all participant comments were transcribed and collated. We then analysed the consolidated workshop transcripts, and used structured thematic mapping to identify the underlying issues that stakeholders believed contributed to the AMD management challenge, as well as the opportunities for improvements in the AMD business case.

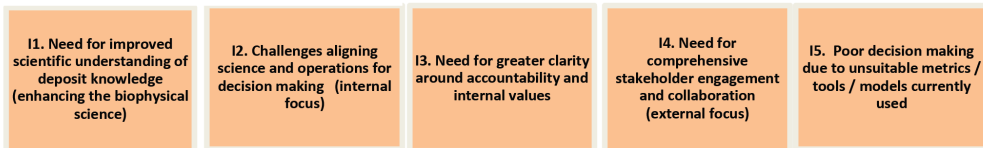
## Results and discussion

Five core Issue Themes and five core Opportunity Themes were identified (Figure 1) with each of the themes discussed in the following sections.

The identified ten issues and opportunities were then categorized into four broad themes:

- A. Enhancing the business case for AMD management
- B. Engagement, communication and education.
- C. Standards and governance.
- D. Understanding the science of AMD.

### Identified core issue themes:



### Identified core opportunity themes:



Figure 1 The identified core issue themes (I1-I5) and opportunity themes (O1-O5) that resulted from open space and dialogue mapping processes.



The following section gives a brief description of the aspects embedded in each broad theme and the associated issue and opportunity themes.

### 1. *The business case for AMD management*

The critical need for integrated management of AMD throughout the life-of-mine is the common thread across the ten themes; this has long been known yet continues to be perceived as currently lacking in many organisations. For example, enhancing AMD business case requires convincing decision-makers that pro-active AMD management is financially sensible. However, difficulties in identifying long-term environmental and social risks and quantifying those late costs using cost evaluation processes such as Net Present Value (NPV) tools, can lead to an inaccurate apportionment of cost over time and discourage timely AMD action. This makes it challenging to communicate convincing economic arguments favouring early and pro-active AMD management. Processes that establish collaboration across different work areas and disciplines and promote improved cross-organisation understanding of specific practices, norms, and tools can be used to provide credibility to AMD risk analysis and stimulate the development of a more robust business case.

Improved risk assessment programs, integrated screening and risk review protocols have been developed and implemented at some mines for a better management of AMD and closure planning. Nevertheless, there is still a failure to systematically manage AMD adequately (Commonwealth of Australia, 2019) signaling ongoing "blind-spots" in the mitigation of AMD risks. These blind spots have previously been related to a multitude of factors, geological variability and lack of deposit and repositories knowledge, inherent technical limitations of AMD testing, decision-making based on inadequate tools or insufficient monitoring, lack of internal accountability processes and ineffective engagement with the full range of stakeholders (Lottermoser, 2015). In this study the following issues were unveiled:

#### a. **Identified issue: Challenges aligning science and operations for decision making**

There are challenges in aligning knowledge of site-based mineralogy and AMD geochemistry with management approaches to mine planning and operations. Participants highlighted that when combined with a risk-averse mindset, this reinforces the focus on AMD treatment at the end of the mine life, when fewer mitigation options are available. Companies frequently opt for treatment options that may not be the most environmentally and social-economically sustainable in the long term.

#### b. **Identified issue: Poor decision making due to unsuitable metrics / tools / models currently used**

Decision-making instruments used for long-term strategic assessments such as NPV are inadequate and their application is not integrated across disciplines. The lack of clarity on future consequences and risk of AMD at the start of an operation, combined with the current set of organisational values and norms puts the management focus on short-term risks resulting in improper evaluation of long-term risks and costs.

#### c. **Identified opportunity: Quantifying residual risk to improve the business case**

There is a need for business plans to include a risk analysis of different AMD impact scenarios, in particular residual risk frameworks for closure planning, to determine different cost scenarios, the associated liabilities, and the resultant annual cash flow during operation, closure and post-closure stages. Framing risk scenarios in terms of ongoing management rather than for the closure stage, would ensure management for relinquishment would start at beginning of life of mine.

### 2. *Engagement, communication and education*

Despite adopting sustainable principles and Corporate Social Responsibility (CSR) initiatives and supporting increased stakeholder collaboration and engagement and guarantee a social license to operate (SLO), mining companies have not fully incor-

porated social-economic accountability and environmental success criteria into all decision-making processes and business models (Frederiksen, 2018). Developing and effectively implementing new accountability frameworks, establishing improved practices of cross-department dialogue and platforms that inform decision-making are required for improved accountability and better management outcomes in the mining industry (Kemp *et al.*, 2012).

In addition to the deep understanding of the long-term financial liabilities of AMD, a sustained commitment to improved AMD management requires interdisciplinary collaboration practices. However, discipline-specific language and lack of formal cross-disciplinary communication tools, often result in lost opportunities to promote awareness across different teams and influence hierarchies of decision-makers. Thus, knowing how to communicate across teams and developing collaboration practices across departments is paramount to getting key messages across to people with different skills, capabilities and responsibilities.

**a. Identified issue: Need for comprehensive stakeholder engagement and collaboration**

There is often a remaining misalignment between industry interests and community aspirations. As a result, mining operators may remain detached from the complexities of the environmental and social-economic realities in which they operate, and their business practices are often biased towards sharing “selective” information with local communities.

**b. Identified opportunity: Educate and inform professionals**

Developing a rigorous business case to influencing mine planning, requires a better understanding of how technical risks can be materialised into financial risks and how to communicate these effectively from a financial perspective. Greater on-job training courses, targeting cross-pollination between disciplines whilst fostering more interdisciplinary collaboration and avoiding a silo culture will also promote greater access to key decision-making processes.

**c. Identified opportunity: Enhance communication and collaboration**

There is a need for improved structured communication and collaboration processes that create more comprehensive and holistic engagement with external stakeholders, particularly with local mining. Communication and collaboration with external stakeholders, is a vital way to tackle concerns by companies, governments and societies, at both local and global levels.

**3. Standards and Governance**

The regulation of mining activities in Australia is complex with regulations relevant to environmental AMD impacts, fragmented across Commonwealth, State / Territory and Local Government jurisdictions. Statutory instruments are used to assess the environmental risks and suitable corrective / mitigation measures. However, these tools do not explicitly regulate AMD nor the production and release of acidity. Federal law regulates environmental protection and – therefore – the actions likely to significantly impact water bodies ecosystems and biodiversity, but does not specifically address AMD risks (Commonwealth of Australia, 2016).

**a. Identified issue: Need for greater clarity around accountability and internal values**

Internal organizational practices and accountabilities are intertwined with internal stakeholder interests and objectives. Participants highlighted current tensions between short and long-term objectives, caused by different priorities being adopted across the organisation hierarchy.

**b. Identified opportunity: Standards, governance and regulation**

Regulatory frameworks around environmental impacts, particularly related to AMD, need further consideration to understand aspects that may block, undermine or conflict with mining project goals, adequate post-closure management and long-term mine rehabilitation. Participants called for improved identification of regulatory gaps or loopholes that jeopardise closure goals.



4. *Understanding the science of AMD*

The mining sector is capital intensive and cyclical in nature resulting on a focus on controlling operational costs and improving productivity. Industry culture and organizational structures create hesitancy in trusting external stakeholder knowledge and capabilities leading to obstacles in the diffusion of innovations and collaborative partnerships to develop new solutions (Gruenhagen & Parker, 2020). In addition, high costs in scaling up new technologies, complexity of integrating these with site operations and the challenges in deploying to geographically remote areas means that implementation of large-scale application of alternative remediation processes is rare (Skousen *et al.*, 2019).

**a. Identified issue: Need for improved scientific understanding or deposit knowledge**

Knowledge of geological resource characterisation is often still incomplete, resulting in gaps in site-based prediction and remediation strategies of AMD. Participants highlighted a need for improved source control charac-

terisation, and adequate segregation of materials based on their geochemical characteristics.

**b. Identified opportunity: Improve knowledge of source control and value opportunities**

Results from detailed characterization can help identify and accurately quantify minerals and elements of concern for potential AMD impacts and improve the integration of AMD management with mine planning processes and operational tools. There is a need for improved practices and processes for AMD prediction and prevention and for the creation of economic value from AMD.

*Where to from here for CRC TiME*

Based on the emergent themes, a roadmap was created (Table 1) to identify the areas where future CRC work could make the most impact in helping improve a business case to minimise AMD risk across the mining life cycle. The outlined scope for each theme is based on the workshop discussion. In each case, we have highlighted the work to be done in the short and medium term.

*Table 1 Suggested AMD research themes, summary of related scope and their timelines*

Short Term (0-3 years)	Medium Term (3-6 years)
<b>Enhancing the business case for improved AMD management</b>	
<ul style="list-style-type: none"> <li>Develop methodologies to support the required transitions in organization maturity relating to mine closure generally, and AMD management specifically.</li> <li>Undertake a case study audit of KPIs and their timeframes, across the whole of business, identifying where conflicts arise for AMD management.</li> </ul>	<ul style="list-style-type: none"> <li>Improve frameworks to adequately quantify risks and opportunities throughout mine-of-life, particularly for mine closure planning and associated residual risks.</li> </ul>
<b>Educate and inform cross-disciplinary professional teams</b>	
<ul style="list-style-type: none"> <li>Identify skills needs and education required to capture closure challenges in the business case for improved AMD management.</li> </ul>	<ul style="list-style-type: none"> <li>Deliver educational resources for cross-disciplinary teams, to facilitate a shared understanding of AMD risks.</li> </ul>
<b>Understand community aspirations for AMD-affected lands</b>	
<ul style="list-style-type: none"> <li>Explore how to improve traditional owner and community awareness of AMD.</li> <li>Explore opportunities for two-way science with traditional owners of AMD-affected lands.</li> <li>Use traditional owner and community aspirations for the future use of AMD-affected lands, to drive AMD and closure research.</li> </ul>	<ul style="list-style-type: none"> <li>Develop effective AMD communication resources with adequate language and messages for different stakeholder groups, based on their concerns.</li> <li>Develop platforms to share (anonymized) operational data and to improve community and investor engagement.</li> <li>Select demonstration sites and develop case studies of both failures and success in AMD management and the relinquishment of AMD-affected land.</li> </ul>



Short Term (0-3 years)	Medium Term (3-6 years)
<b>Enhance standards, governance and regulation</b>	
<ul style="list-style-type: none"><li>• Develop approaches for governance of regional-scale AMD management, with consideration for cumulative impacts on regional economies.</li><li>• Assess operational and regulatory barriers that may limit social and environmental monitoring and reporting, and the associated liabilities.</li></ul>	<ul style="list-style-type: none"><li>• Review and evaluate the decision-making processes that underlie the existing permitting conditions with respect to AMD (water pollution).</li><li>• Develop new regulatory approaches that can be used to improve outcomes, based on specific site-level environmental constraints.</li></ul>
<b>Improve knowledge of source control, remediation and value opportunities</b>	
<ul style="list-style-type: none"><li>• Improve our understanding of source control and materials handling through accurate forecasting of AMD.</li><li>• Through geochemical risk assessments, evaluate opportunities in reprocessing waste and converting AMD into a valued product.</li></ul>	<ul style="list-style-type: none"><li>• Develop predictive models of current and future AMD risk, to support long-term AMD governance.</li><li>• Validate remediation and valued-added technology focussed on scale-up studies.</li></ul>

## Conclusions

The complexity of the AMD intractability problem reflects a multidisciplinary challenge and is embodied by consolidated operational practices that do not serve proactive management and obstruct the required cultural shift. The multifaceted and wicked nature of AMD management comprises a critical challenge in adequately defining the root cause of the problem and developing methods to understand it, let alone creating solutions.

The interdisciplinary stakeholders' collaboration method used in this study expanded on the previous understanding of the AMD management challenges by identifying blind-spots and underlying issues and opportunities. This "opportunity-driven" method identified ten themes as the critical areas where further research is required to adequately address the AMD problem (five issues themes) and its potential solutions (five opportunities-themes). The clarity of the emerged themes demonstrates the methodology's capacity to unveil collective tacit knowledge and explicitly detect underlying issues and associated new questions (opportunities).

The identified themes do not call for small incremental improvements in our knowledge about AMD; they call for cultural shifts within organisations. Divergent responsibilities, conflicting key performance indicators (KPIs), narrow risk assessment

approaches, and short-term decision-making strategies often conflict with the long-term and interdisciplinary approaches required for optimal AMD management and prevent its effective incorporation into the whole mine life cycle. Transitioning an organisation from compliance with regulatory requirements for AMD management and closure, to integration of mine closure within the whole organisation culture and operations, is dependent on a shared understanding of several key points. All decision-making teams across a company must understand the risks of AMD, future uncertainties they encompass and the lost opportunities if the risk is not mitigated. Ultimately, the internal business proposition for AMD management must be rigorously communicated and underpinned by this shared understanding of its risks.

The full report describing this work is at: [https://crctime.com.au/macwp/wp-content/uploads/2022/10/Project-3.6\\_Final-Report\\_27.10.22\\_approved.pdf](https://crctime.com.au/macwp/wp-content/uploads/2022/10/Project-3.6_Final-Report_27.10.22_approved.pdf)

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