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Enabling change in mine closure: six key challenges and strategies to enable transition planning, management and execution

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Abstract

Over the past decade there has been a shift in the view of mine closure. At a corporate level, escalating closure liabilities, changing societal and investor expectations and increases in active execution of mine closure projects have brought a new perspective. Equally, there has been a significant shift towards transition based approaches, recognising the multi-stakeholder dependencies that exist in achieving relinquishment and asset transfer. Looking ahead, forecasts have highlighted the growth in mine closure and the opportunity that exists in capitalising on the planned investment and post-mine land and asset use. This is a unique time to enable change to reimagine post-mine futures.

In 2024, Cooperative Research Centre for Transformations in Mining Economies (CRC TiME) undertook a review of research completed to date. This included more than AUD 30 million of collective investment across 46 projects, which were informed by more than 100 industry, government, regional, First Nations and research leaders throughout their delivery. To build on what we learnt and accommodate the fast-changing context, we sought to understand both what are the key constraints preventing transformative change and where we could contribute most value over the next five-year period.

Six key areas emerged from this process:

- *supporting corporate leadership in valuing post-mine transitions*
- *operationalise mine closure transition opportunities within mine planning processes*
- *establish the business case for asset transfer*
- *contribute to policy and regulation that minimises negative impacts and maximises benefits*
- *enable regional scale outcomes*
- *support supply chain, education, training and workforce development for closure and post-mine transitions.*

This paper explores each of these six areas, identifying the priority research, First Nations and industry change enablers. The novel framework sets a clear agenda for broadening the debate around mine closure and towards managing transitions throughout and beyond life of mine, to deliver a positive legacy.

Keywords: *CRC TiME, mine closure, strategic planning, transition, post-mine legacy, economic transformation*

1 Introduction

We sit at a time of significant potential to reimagine and transform post-mine transitions. Future opportunities are emerging with an estimated 240 mines expected to close across Australia by 2040, peaking around 2030 (CSIRO 2023). Globally, forecasts by Moody's predict that mining closure/reclamation

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obligations could surpass the industry's total debt by 2033 (Moody's 2024). A key mental shift is required to manage liabilities and realise opportunities – to think beyond closure and returning to the pre-mining state to the focus on post-mining outcomes (Measham et al. 2024).

In 2020, the Australian Government funded the long-term mine closure and post-mine transition research initiative to be delivered between 2020 and 2030 through the Cooperative Research Centre for Transformations in Mining Economies (CRC TiME 2020). The research program was funded on the basis that addressing the poor track record in mine closure and relinquishment required a multi-stakeholder approach, that positioned mine closure within a regional economic transition context. The research framework published in 2020 outlined research themes to explore challenges and opportunities during pre and post transfer of assets that limit beneficial outcomes post mine.

Taking a complex systems approach, the research undertaken between 2020–2025 explored themes relating to post-mine land use; stakeholder values; cumulative regional effects assessment; First Nations inclusion; education; mine closure planning; risk identification and management; and biophysical challenges in water management and ecological restoration. In 2024, CRC TiME undertook a review of research completed to date. This included more than AUD 30 million of collective investment across 46 projects, informed by more than 100 industry, government, regional, First Nations and research leaders throughout delivery. To build on what we learnt and reflect and shape this fast-changing context, we sought to understand both the key constraints preventing transformative change and outcomes, and where we could contribute most value over the next five-year period. Six key areas emerged from this process.

2 Supporting corporate leadership in valuing post-mine transitions

Can we develop a comprehensive business case for post-mining transition?

There still remain a number of areas that challenge the business case for early and sustained investment in interventions that enable post-mine transitions. Historically, there has been a tendency to view closure as a cost at some point in the future – generally after production has ceased and sites are no longer generating revenues. The idea of early investment in actions that enable better post-mining outcomes has struggled to gain traction, and closure teams have often inherited a set of decisions that may not have optimised post-mining outcomes (McCullough 2016).

The current industry practice prioritises maximising net present value (NPV) for shareholders, often presents challenges for post-mine value or risk integration. There is increasing recognition that there is a need for decision-makers to consider a wider set of inputs in the application of NPV; regarding different post-mine transition scenarios and the ways that discounted cash flows (DCFs) are treated in calculations. In broadening NPV calculations and the way we think about DCF, it is crucial to consider non-industry rightsholders and regional stakeholders in thinking ahead to post-mining outcomes (Foran et al. 2024).

Accessing capital is likely to increasingly rely on our ability to accurately forecast and manage closure costs. Studies have noted discrepancies between forecasted mine closure costs and the actual expenses incurred. A recent report by Moody's highlighted closure liability / asset reclamation costs of USD 78 billion in 2023 and forecast potential future implications for accessing capital. Moody's draw attention to natural capital dependencies in the mining industry (Moody's 2024). Their report suggests reclamation obligations could exceed mining debt by 2033.

At the same time, one of the six recommendations made by the USD 15 trillion backed multi-stakeholder Global Investor Commission on Mining 2030, is for collective investor action to create positive legacy impacts (Chronos Sustainability Ltd 2024). The Commission highlights the need to address existing historic legacy issues, as well as to avoid and reduce these issues arising in the future by ensuring good planning and process for mine closure and post-closure transitions.

Finally, creating and demonstrating the value of opportunities for earlier transition of land, infrastructure and wastes to next use/s where transitions risks can be managed and value can be generated, is required to address confidence in an area of limited examples of transition. Representing intangible values of different

post-mine transitions is central to creating a clearer business case for senior leaders, building greater confidence in the acceptance by mine regulators and post-mine stakeholders that closed mines have met expectations and limits 'boomerang liabilities'.

3 Operationalising mine closure transition opportunities within mine planning processes

How do we provide access to leading knowledge, tools and resources to better integrate mine closure and post-mine transitions in asset-level and operational decision-making?

The integration of progressive activities that inform, enable and position mined land and assets closure, and for transition, generally remains an issue. A priority is the identification and integration of post-mine transition key performance indicators into short-term planning processes. This needs better integration upfront of mine closure in mine planning and frequent re-evaluation and updates over the life of the mine.

We identified natural capital accounting (NCA) systems as a mechanism for transparently and consistently assessing and valuing changes over the mine lifecycle (Maybee et al. 2024). Integrating NCA systems with forecast models provides mine planners and mine closure specialists with a more effective tool to evaluate alternative designs, as well as to track progress (Maybe et al. 2023). Based on the UN System for environmental economic accounting, the NCA system has been adopted across many land-based sectors and provides a common platform for planning and tracking landscape scale changes in natural capital (O'Grady et al. 2023).

Key biophysical risk points require targeted and cross industry research and innovation programs to develop solutions. Water management and treatment is a significant cost and limitation for post-mine use. Water is a critical resource for new and existing industries with implications across distances due to the high degree of connectivity in water systems beyond site boundaries and across regions (Cook et al. 2021). We note the importance of research on acid and metalliferous drainage prevention and treatment, as well as mine pit/void design and hydrological understanding to create opportunities for novel post-mine economic or nature positive use of the lakes created.

Creating self-sustaining ecosystems is the second identified risk point for mine sites, with seed and soil availability both key issues. Work is required to develop seed supply chains and optimise seed use to meet the scale of rehabilitation required at a national scale, while integrating guidance and establishing networked trials is important to support the sectors' ability to develop functional novel soils in soil constrained environments. Embedded trial networks provide a platform for advancing practice, both through knowledge generation and transfer mechanisms (Broadhurst et al. 2023).

4 Establishing the business case for asset transfer

What are the top key contributors to levels of residual risk across all aspects of mining, environmental, social, and governance, cultural and regulatory domains? How do we identify acceptable levels of risk for post-mine stakeholders?

Transition, distinct from closure, generally requires the transfer of assets between mining and post mining actors. To date, concerns about residual risk have often prevented the relinquishment of mine leases and transfer of sites to subsequent land users (Tiemann et al. 2019). Focused effort is required both on articulating the different aspects of residual risk and fit for purpose mechanisms that provide confidence between parties in the transfer or sharing of future risk post asset transfer (Maybee et al. 2024). While work has focused on reducing risk, a growing body of work is developing a deeper understanding of the opportunities associated with post-mine land, waste and asset use.

Asset transfer requires focused and trusted mechanisms to evaluate the value proposition for different uses, and build the business case for post-mine stakeholders to acquire the asset. More transparent and wider access to information, through atlas products such as the Australian Mine Waste Atlas, can help the private, public and community sectors to identify opportunities suited to different site characteristics. Finally,

uncertainty associated with asset transfer presents an opportunity to explore securitisation mechanisms, with this opportunity growing as more mines are taken through a full transition process.

5 Contribute to policy and regulation that minimises negative impacts and maximises benefits

How can we assist governments to include greater optionality in policy and regulation, while managing risk, to move beyond return to prior state as the presumed best outcome?

The tension that exists between regulation of post-mine risk with the exploration and execution of value based post-mine uses is a key issue for policy makers and regulators, as discussed in the recent New South Wales inquiry into post-mine land use (Standing Committee on State Development 2025). Statutory goals for mine closure are primarily expressed through a risk minimisation lens, with safe, stable, non-polluting and self-sustaining land uses noted as success. This is disconnected from economic development or natural capital optimisation narratives that focus on realising potential from the unique features and characteristics available in post-mine land and asset use planning. Critically, realising net positive outcomes also rely on attracting human capital (Foran et al. 2022)

Beyond residual risk noted above, a key issue that has been identified include tenure models that limit optionality and constrain post-mine investment. The inability to establish alternative tenure for repurposed mine sites has been the primary justification for pre-mining land use as the default. The constraint is that mining itself is not 'tenure' and the tenure of the underlying land will generally be held by a party other than the mining company. Transition must therefore have the consent of the tenure holder, as well as be supported by a land administration system that allows for change in tenure. New pathways are emerging. For example, in Western Australia amendments to the Western Australian Land Administration Act (1977) in 2023 have created a pathway to resolve the tenure constraint so that multiple land-uses can co-exist (Western Australian Department of Planning, Lands and Heritage 2023).

Multi-stakeholder governance models that build consensus around potential post-mine transition options, including through multi-stakeholder and agreement-making processes are needed. Multi-stakeholder approaches can take a wide variety of forms, depending on the timing, focus and context. Although every situation is unique, there are some general principles, common lessons and techniques that are relevant to other situations (ICMM 2025). Working across all tiers of government, settings that support and enable multi-stakeholder decision-making processes to optimise outcomes are critical.

At the same time, an opportunity exists across Australia for multiple jurisdictions to identify and develop shared principles and a roadmap for mine closure and post-mine transitions. This is responding to the shared challenge and opportunity being explored in each part of Australia as more mines reach maturity; importance of First Nation peoples and other rightsholders participation in post-mine transition decisions; and growing recognition of circular economy-based productivity from mined land and assets.

Moving from mine closure to transition is a fundamental shift and principles are needed to provide a framework for new policies ensuring consistency; clarity; and alignment to statutory goals – a key gap identified in previous reviews (Hamblin et al. 2022). Reliance on 'soft law' through guidance documents remains central, but in a growing environment of documentation a framework and toolkit that draws on evidence-based guidance is required to support transition-based policy implementation.

6 Enable regional scale outcomes

How do companies with multiple stakeholders and rights holders deliver transitions that align with regional scale goals and planning?

Mines are mostly managed and regulated at the site scale. Over time, attention to the cumulative effects of mines has emphasised the need to consider the regional scale for post-mining outcomes (Everingham et al. 2018). Mines are embedded in regional economies, connected in multiple ways including infrastructure;

labour forces; housing markets; and supply chains. Enabling post-mining outcomes requires attention to all of these different dimensions (Marais 2025).

Whether mines are isolated or co-located within a region, their effects are felt through regional economies, communities and landscapes. Regional cumulative effects assessment and management is crucial for mine closure, as it helps to understand and manage the cumulative environmental; social; cultural; and economic impacts that can arise from mine closure. This systematic approach facilitates informed decision-making, supports the development of post-mining land use, and enables better planning for socio-economic transitions in mining regions.

A second priority is ensuring there is greater understanding of the future economic pathways for regions to help prepare communities for the loss of a key economic driver and ensure a sustainable transition to alternative industries. This knowledge allows for proactive planning, diversification, and the development of strategies to mitigate the social and economic impacts of mine closure.

Finally, collaborative planning approaches are central to enabling an enduring and supported post-mine transitions. Developing a shared vision and understanding across relevant parties including communities, industry, government agencies and First Nations groups, and recognising the importance of intergenerational engagement, helps reduce conflict and build buy in to ensure transitions are supported (Finucane 2024).

These approaches need to be paired with growing the capability of rightsholders and stakeholders to engage in planning processes, with cross regional knowledge exchange mechanisms providing opportunities for different stakeholders to learn from each other, build networks, and gain lessons for different regions undergoing transitions.

7 Support supply chain, education, training and workforce development for closure and post-mine transitions

> *How do we build a connected post-mine transition and closure supply chain and ensure the future mining and mining equipment, technology and services workforce have capacity to deliver on mine closure solutions and post-mine transitions?*

In recent years, reports have highlighted the scale and forecasted growth in mine closure and transitions, the diversity of skills and activities required and the need to develop a dedicated workforce strategy and implementation plan. There is a clear need to raise the level of awareness and understanding about mine closure and post-mining transition across all parties involved. Within mining companies, closure is well understood by closure teams, but less well understood by other parts of the business. Moreover, there is a key need to increase the level of understanding amongst all the other parties involved in post-mining transitions including regulators, First Nations groups and regional communities.

In 2024, a review commissioned by CRC TiME (Dejkovski 2024) – and undertaken by the Mining and Automotive Skills Alliance and Business Skills Victoria – noted how crucial mine closure education and training program development is to the successful transition of mine sites post-closure, while highlighting that a nationally consistent mine closure curriculum or program that addresses the complexities of mine closure does not exist.

Education and training opportunities are required and are scalable, including micro-credential, vocational education and training, higher education and postgraduate opportunities. This recognises the upskilling and reskilling required in core areas to support closure integration, such as through finance, mine planning or on ground roles such as earthworks execution, as well as emerging areas such as NCA and environmental stewardship.

Addressing skill gaps is also critical, highlighting the diversity of technical skills in socio-economic and biophysical aspects of closure throughout and beyond the life of the mine. First Nations communities, often deeply affected by mining activities, are at the centre of vocational programs that combine traditional knowledge with contemporary skills to contribute to and realise opportunities presented through post-mine transitions.

8 Conclusion

These six themes, representing the key constraints that hinder effective post-mine transitions, reflect a set of considerable challenges. It is important to recognise that the six themes are interconnected, therefore we need to approach them collectively. Supporting corporate leadership in valuing post-mine transitions by presenting a well-informed rationale and business case for investing in activities that enable post-mine transitions, will benefit from establishing the business case for asset transfer and from a policy environment that minimises negative impacts and maximises benefits.

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