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Envisioning the future: Does imagery help or hinder?

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Abstract

As the saying goes, a picture says a thousand words. Across contexts, cultures and time, images share knowledge, inspire emotion, envision the future and build connections. But, as a means of communicating likely post-closure outcomes, are visualisations and images, including 3D visualisation, useful when pits and waste dumps have yet to be built and rehabilitation is likely to occur decades into the future?

Visualisations of intended post-closure landscapes draw on various data sources as well as assumptions and creative imagination. These are often provided to stakeholders to inform, consult and, more recently, support joint decision-making about mine development, operations and post-mining landscapes. Generally, use of visualisations is seen as positive.

Yet it comes with risks. While useful to increase awareness, undertake scenario planning and support discussion, these visualisations may not represent achievable outcomes or post-closure landscapes. There may also be differences in how individuals interpret visualisations.

This creates a significant challenge. Visualisations are useful — and often needed — to enable stakeholders to provide guidance on preferred post-closure landscapes and future uses. And evidence of stakeholder input and consultation is required to secure regulatory consent to commence development.

Furthermore, once a project begins, assumptions, environmental understanding, mining decisions and other factors that underpinned these visualisations may change. Even where the fundamentals of mining may not change, the aspects influencing visual amenity of landscape may. There is a risk they may live on only in the memory of stakeholders.

This paper explores the pros and cons of using post-closure landscape visualisations as part of stakeholder engagement processes before operations cease. As we enter the artificial intelligence (AI) age – with more easily rendered artificial visualisations being flexible sources of fact – understanding and managing these pros and cons is critically important for transparent communications, ensuring informed consent and supporting respectful partnerships.

It also recommends protocols on the provision and use of post-closure visualisations, in consideration of the confidence to deliver that outcome, to enable stakeholders to distinguish, at a glance, between the ambitious, the possible and the pragmatic.

Keywords: *stakeholder engagement, visual amenity, visualisation, post-closure land use, trust, AI*

1 Introduction

In this paper, 'stakeholder engagement processes' describes the various ways in which rights holders, landholders, community members and others are engaged about matters relating to mine closure and transitions. Furthermore, we have used the term 'stakeholder' broadly, encompassing rights holders,

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landholders, community members and others with rights and interests relating to mining and mine closure. This includes First Nations communities, including Indigenous landholders.

Visualisations and imagery (described as visualisations in this paper) are often seen as 'powerful tools for communicating scientific outcomes of environmental planning models' (Pettit et al. 2011). It is not surprising, therefore, that various forms of visualisation technologies, including maps, 3D imagery and now virtual reality, are used by mining companies and others to communicate, consult on and, in some cases, make shared commitments with and to stakeholders about the spatial arrangement, visual appeal and other aspects of intended post-closure landscapes.

Visualisations of intended rehabilitated landscapes have been used in stakeholder engagement processes for environmental approvals for decades, with techniques generally keeping pace with technological advances in computer game graphics. As illustrated in Figure 1, it has evolved from hand-drawn, artistic renderings in the 1970s to computer-aided 3D rendering in the 1990s. It then transitioned to realistic photo simulations in the 2000s. In the 2020s, a range of visualisation technologies are now available, ranging from 3D visualisation videos to augmented virtual reality and mixed reality experiences that enable stakeholders to stand in the existing, physical landscape and see visualisations of intended future rehabilitated landforms projected into the real world.

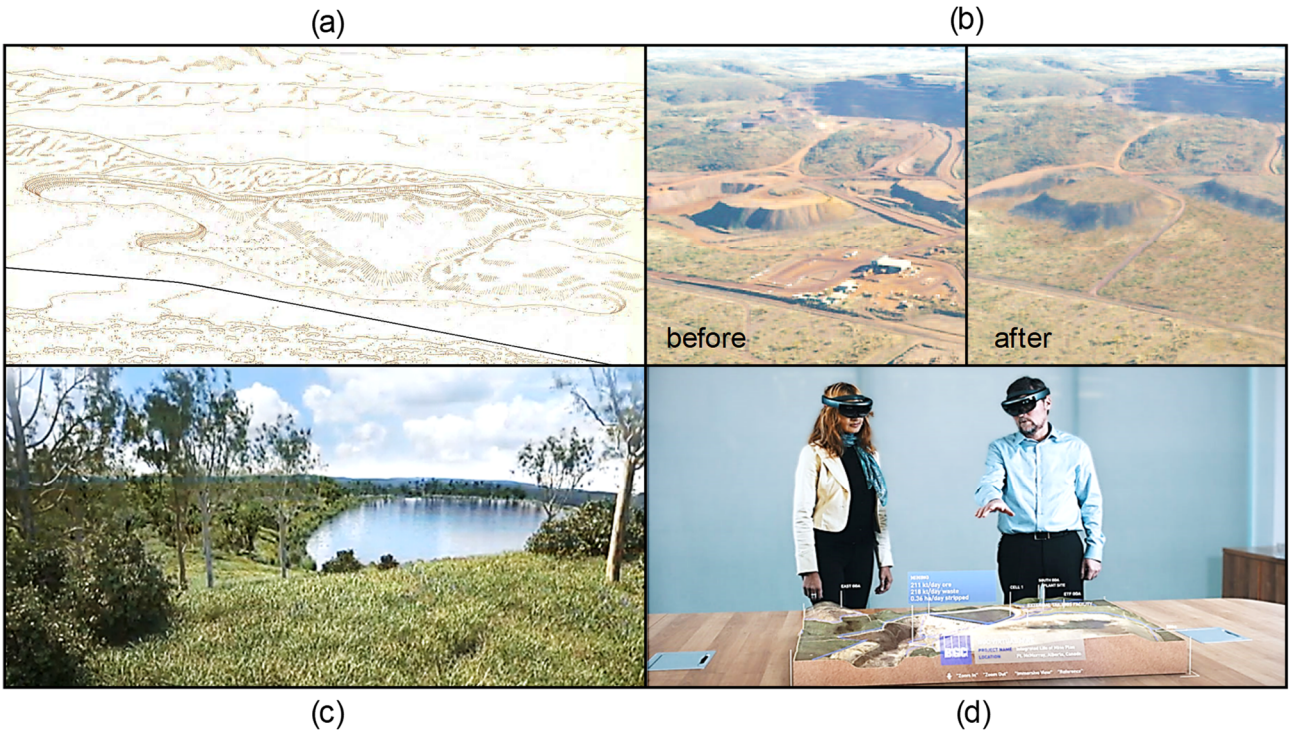

Figure 1 Landscape visualisation styles used to represent rehabilitated landscapes in stakeholder engagement: (a) 1970s artistic sketch (Brian J O'Brien & Associates 1992); (b) 2000s photo simulations (BHP Billiton Iron Ore 2005); (c) 2010s video visualisation (Glencore 2014); (d) 2020s mixed reality (Samaei et al. 2024)

Visualisations are being used to support collaborative planning for recently ceased operations and abandoned sites. For example, Charles Darwin University (2022) is working with Energy Resources Australia, Gundjeihmi Aboriginal Corporation and the Northern Land Council to produce 3D printed models of rehabilitation processes and outcomes at the Ranger mine site in the Northern Territory, Australia. Rehabilitation is due to be completed at Ranger around 2028 (Charles Darwin University 2022).

Visualisations are compiled from various sources, such as baseline environmental and digital elevation data, assumptions (e.g. modelling predictions) and creative imagination. It is then presented in a variety of forms as part of stakeholder engagement processes to inform, consult and, more recently, make joint decisions.

When presented in facilitated sessions, stakeholders may understand that visualisations are indicative, provided to spark discussion and, while developed based on current understanding, may not eventually represent the actual post-closure outcomes or landscapes.

Using those 'representative' visualisations, stakeholders are often asked to provide guidance on desired outcomes and future land uses. Imagery may also be required as part of regulatory approvals.

Once a project begins, however, assumptions, environmental understanding, mining decisions and other factors that underpinned presented visualisations may change. Even where changes may not be significant, aspects that influence the visual amenity of the landscape may be (e.g. waste dumps and pits built in slightly different locations and with slightly different materials, etc.). There is a risk that originally envisaged post-closure landscapes endure only in the memory of the stakeholders.

The provision of imagery and disclosure visualisations that are 'representative but not accurate' are important. However, approval processes are evolving in line with stakeholder expectations, and a shift to include 'preliminary' closure landscape visualisations in social and environmental visual impact assessments during the approval process has commenced. This appears to reflect an evolution in the social contract for mining to include more robust stakeholder engagement processes as well as a presumption that land can, and should be, returned to its prior state or, at the very least, a prior use.

As we enter the artificial intelligence (AI) age, with easily rendered artificial imagery and potentially flexible sources of fact, understanding and managing the challenges of using or generating future-looking visualisation aids is critically important for effective and transparent communication.

In this paper we focus on the use of forward-looking imagery, i.e. images produced before or during mining (prior to the cessation of operations) that depict intended rehabilitated, post-closure landscapes.

In Section 3.1 we present the pros and cons of using imagery in general in stakeholder engagement, as reported in literature and through our personal experience. In Section 3.2 we review of mining industry stakeholder engagement guidance and selected regulatory guidance for mine closure plan development. This aims to clarify guidance for the use of forward-looking visualisations and understanding regulatory drivers for inclusion in regulated, publicly available information (e.g. a mine plan).

In Section 4 we recommend future research directions to improve transparency and reduce bias when forward-looking post-closure landscape visualisations are used in stakeholder engagement processes. We provide early guidance to support more effective, deliberative and transparent engagement processes when utilising future-looking closure visualisation tools Finally, we propose a visual aid be added to imagery to provide context on the maturity of the image, helping to distinguish between ambitious, possible and pragmatic post-closure landscape imagery.

2 Methodology

2.1 Stakeholder engagement guidance

Industry standards and guidelines establish expectations for consultation, engagement and, where applicable, processes to ensure free, prior and informed consent. Industry standards and guidelines can be influential on company practice, especially where entities are required to demonstrate performance against practice (International Council on Mining and Metals [ICMM] 2023). Our rapid review targeted stakeholder engagement is associated with future-looking closure discussions; recognising that the nature and scope of stakeholder discussions change and expand significantly once closure of a mine is imminent (ICMM 2019, 2022).

With Australian industry guidance (Department of Industry, Tourism and Resources [DITR] 2009; Grant et al. 2016) generally silent on the topic of visualisation, we highlight three ICMM guidelines published between 2019 and 2023. Table 1 summarises the stakeholder engagement guidance references to future-looking imagery. Results are discussed in Section 3.2.

Table 1 Summary of specific references to image use in global stakeholder engagement guidance (extracted from stated guidance)

Guidance	Stakeholder engagement requirements	References to imagery use
ICMM (2019) Integrated Mine Closure: Good Practice Guide (2nd Edition)	Recognises the importance of ongoing updates to internal and external stakeholders on progress and issues, including showing evidence of effectiveness and that conditions can be met Describes stakeholder involvement in the development of success criteria	Describes 3D models as 'useful' but not as a key aspect of stakeholder engagement processes Identifies good practice as developing maps of post-closure landscapes and evaluating areas with common capability. Notes that post-mining land use planning becomes more detailed over time
ICMM (2022) Closure Maturity Framework: Tools for Closure User Guide	Describes leading practice as exploration, design and construction phase as company defining success criteria based on regulation review, stakeholder engagement and risk Describes international good and leading practice during operations as collaborative engagement with key stakeholders on closure planning, including setting a vision and post-mining land use options with these reviewed and feedback integrated regularly Notes that the final closure plan should be based on sound, up-to-date information collected during operations (including feedback)	Identifies leading practice as potential land use being mapped at a high level, taking into account stakeholder reviews and land capability No reference to how visualisations should or could be used
ICMM (2023) Performance Expectations	Work to obtain the free, prior and informed consent of Indigenous peoples where significant adverse impacts are likely to occur as a result of relocation, or disturbance of lands and territories or critical cultural heritage, and to capture outcomes of engagement and consent processes in agreements Plan and design for closure in consultation with relevant authorities and stakeholders, implement measures to address closure-related environmental aspects, and make financial provision to enable agreed closure and post-closure commitments to be realised	No reference to how visualisations could or should be used

2.2 Industry regulation

Within Australia, state and territory laws and instruments stipulate what is required for mine closure plans submitted to regulators. We reviewed closure plan development guidance in Australia to identify whether there was a regulatory requirement to include forward-looking imagery, such as final landform designs or post-closure landscape visualisation, in plans or any similar expectations recommended when engaging stakeholders.

Only guidance in Western Australia and Queensland makes references that could be construed as relating to future-looking visualisations. Table 2 summarises these. Results are discussed in Section 3.2.

Table 2 Summary of post-closure landscape imagery references in mine closure plan development guidance

Jurisdiction	Guidelines	Reference to post-closure landscape imagery
Western Australia	Department of Mines, Industry Regulation and Safety (DMIRS 2020) Mine Closure Plan Guidance – How to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans	Requires information including, but not limited to, design and construction of landforms and voids, including a diagram/map showing a design concept based on post-mining land use to illustrate this in visual form (e.g. 3D diagram/map)
Queensland	Department of Environment and Science (DES 2023) Guideline — Progressive rehabilitation and closure plans (PRC plans)	Requires the final landform design to be based on proposed post-mining land use and non-use managed areas, including 3D design of the final landform States that community consultation should be used to inform outcomes in the PRC plan.

3 Results

3.1 Visualisation use, benefits and challenges

Our literature review highlighted a range of perceived benefits in the use of visualisation technologies and techniques as part of stakeholder engagement processes. These include, but are not limited, to the ability to:

- Bring together and visualise multiple data sets, including cultural, social and environmental attributes.
- Convey complex information more effectively than when compared to text-based explanations.
- Support scenario analysis and consideration, to develop a shared vision.
- Encourage interest and engagement in particular matters (Pettit et al. 2011).

From a mining perspective, use of visualisations can assist to:

- Quantify spatial relationships between mining endeavours and stakeholder cultural, social and environmental attributes, to inform risk identification and design.
- Define verifiable measures of success (completion criteria) through a process of communicating, consulting and, in some cases, making decisions about post-mining landscapes, including landforms, vegetation and other attributes (ICMM 2019).

This can help build stakeholder confidence in the ability of a mining company to deliver positive environmental, social and environmental outcomes (DITR 2009). However, positive interactions through these stakeholder engagement processes are not only important for building support for mine development: Stakeholder confidence needs to have evolved to a level of endorsement by the time closure activities are complete if a company is to achieve its obligations to relinquish tenure (ICMM 2019).

Challenges, critical issues and limitations in the use of imagery and visualisation technologies in stakeholder engagement that have been identified include:

- differences in how stakeholders interpret information (Pettit et al. 2011), with limited research on how end users rely on and use visual information in their decision-making
- concerns regarding disclosure of underpinning assumptions and limitations (Pettit et al. 2011), e.g. use of unrealistic commitments to obtain mining permits (Landform Design Institute 2021).
- misapplication of visualisations where intended as a tool for decision-making rather than an end outcome (Pettit et al. 2011, Resources Regulator 2024). This could include presenting a 3D landscape model visualisation developed to identify and communicate geotechnical, water and other risks as a predictive model illustrating definitive closure outcomes
- reliability and confidence in data used to inform designs that underpin the visualisations (Resources Regulator 2024). There is also limited evidence that it supports successful rehabilitation outcomes (Kragt et al. 2019).

With the expected increase in the provision of post-mining landscapes to assist stakeholder engagement processes (CSIRO 2023), it is important that steps are taken to address these challenges.

3.2 Industry guidance

Industry guidance about mine closure places significant emphasis on stakeholder engagement processes, with expectations of good practice including collaborative engagement to define a vision for closure, post-mining land use options and success criteria (ICMM 2019, 2023).

Yet there was limited, if any, reference to the opportunities, limitations and risks associated with imagery/visualisations in the context of stakeholder engagement in industry or regulator guidance. Similarly, we could not find any specific guidance pertaining to the use of future-looking post-closure landscape visualisation in landscape and visual impact assessment studies completed for environmental approvals.

There is a requirement for final closure landform designs to be provided in mine closure plans in Western Australia and Queensland. However, these regulators are aware that designs within the plans may change over time, and regulatory processes allow for plans to be resubmitted when those changes occur (DMIRS 2020).

There is a growing demand, however, for mine closure plans to be provided to other stakeholders, both external and from within the mining company, to ensure all closure risks are identified (DMIRS 2020). In such cases it could be reasonable for these stakeholders to consider that visualisations presented as 'final' are unlikely to change. If so, we posit that it is reasonable for this assumption to inform their input and/or decision-making.

4 Discussion

4.1 Future research directions

Stakeholders must be able to interpret and understand the inherent limitations present within the imagery, regardless of the visualisation technique utilised, to meaningfully participate in stakeholder engagement processes (Pettit et al. 2011).

Our analysis has identified a need for further research on how post-mining land use visualisations are used to inform stakeholder engagement processes, including how stakeholders interpret, trust and rely on/use mine closure information presented in a visual context.

It is important for future research to consider the use of visualisations from different perspectives, particularly those commissioning visualisations (e.g. proponents), those developing visualisations (e.g. service providers), and stakeholders using visualisations to understand, inform and make decisions about projects and related activities (e.g. Traditional Owners, pastoralists, community members, internal stakeholders, etc.).

As a starting point we propose future research in four key areas:

- stakeholder and proponent experiences, expectations, assumptions and concerns regarding closure visualisations
- evaluation of the current use and accuracy of closure visualisations (including superseded yet still publicly available information) at different stages of the mine life cycle
- assessment of the data sources (factual and subjective) used to construct, inform and illustrate the closure visualisation
- establishment of closure visualisation protocols (discussed in Section 4.2) when presenting closure imagery or using visualisation tools (e.g. virtual or augmented reality) to communicate closure outcomes.

Below we provide some additional thoughts on the development of closure visualisation protocols and the use of a visual watermark on closure visualisation.

4.2 Closure visualisation protocols

Based on the above assessments, we conclude that ambiguity associated with the use and accuracy of visualisations could create business risk by affecting stakeholder support.

We recommend that closure visualisation protocols be established to address inherent weaknesses and limitations associated with generating future-looking imagery for stakeholder engagement processes.

Key aspects to address in the protocols include:

- the basis for data/information inclusion or exclusion during image development
- procedures for communicating inherent uncertainty, reliability and visualisation intent — most notably, differentiation of the model input/output visualisation used as a management tool versus predictive post-closure outcome models
- processes for maintaining up-to-date, publicly facing, post-mining landscape visualisations informed by evolving information about ground conditions, changes to the mine plans and rehabilitation designs, and results of field trials.

Further research on protocols will take time. In the interim, we recommend that proponents consider applying the following when using utilising future-looking closure visualisations:

- Describe what data was used to inform production of the visualisation.
- Describe the purpose of the visualisation, e.g. to inform stakeholder engagement prior to mine development, to inform scenario planning during the active closure phase or to communicate commitments more broadly, etc.
- Ensure that imagery, as far as possible, accurately depicts the surrounding social and environmental context.
- Explain who advised on the landscape design, including what consultation has been undertaken with subject matter experts and stakeholders, and how it has been integrated into the landscape.
- Ensure that limitations to future land use, including access restrictions and unstable/unsafe zones, are clearly depicted in visualisations.
- Advise that mine plan changes may result in changes to indicative final landscapes, and clarify if, when and how those changes will be communicated to stakeholders.
- Be clear on how visualisations will be updated to reflect changes to the mine plan, new data and other inputs.

4.3 Visual distinguishing watermarks

It is common for closure visualisations to be reused, published online or presented in other forums, making them available to a broader group of stakeholders including those from other regions or jurisdictions. This practice will likely continue, especially due to the significant amount of resources, time and effort invested in developing these visualisations as well as increasing stakeholder requests for information. However, this can mean that visualisations are presented and discussed without the originally intended caveats and cations.

Watermarking is a process of embedding a recognisable, unique signal into an image (or text) as a unique identifying feature. It is being considered for use on imagery generated by AI to control the spread of misinformation, such as the generation of 'deepfake' imagery (Craig 2023).

We propose applying a watermark to closure visualisations using two critical pieces of information: date and maturity. Specifically, this would be:

- date — when the image was created. This may help with the image being linked to a specific mine closure plan and the associated data/information that was available to develop the image. If the mine closure plan has been revised substantially since the image was generated it is reasonable to assume that the closure visualisation is outdated
- maturity — what level of information was used to develop the visualisation. This is could be as simple as a qualitative indicator based on recognised knowledge maturity stages
    - conceptual, i.e. theoretical or ambitious, based on general industry practice
    - feasible, i.e. possible or achievable based on completed characterisation and as-built operating designs
    - planned, i.e. predictive post-closure landscape arrangement based on approved, definitive closure designs and agreed closure outcomes.

Figure 2 provides an example of a watermark and Figure 3 illustrates the presentation of a watermark on an image. This type of watermark could help stakeholders to distinguish and differentiate between ambitious, possible and pragmatic closure visualisations.

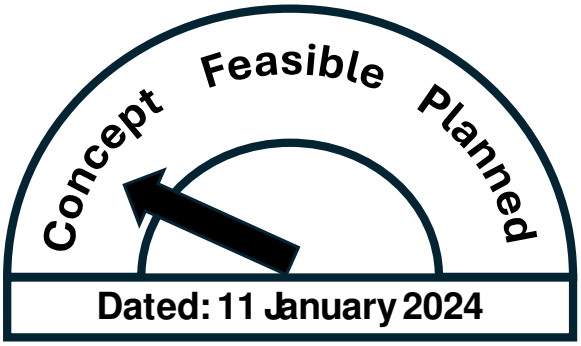

Figure 2 Example of a watermark that can be used to convey image reliability and the date it was generated

Figure 3 Example of a watermarked closure visualisation. Image generated by Copilot from the prompt 'rehabilitated mine pit lake in the Pilbara'. Copilot is a generative AI service provided by Microsoft

5 Conclusion

We conclude that, while the many benefits of using future-looking closure visualisations are often discussed, there is an absence of frameworks, protocols or guidance available to the mining industry, regulators or others on their use to support effective and transparent engagement.

Stakeholders must be able to interpret and understand the inherent limitations of closure visualisations to meaningfully participate in stakeholder engagement processes, including those about future land uses, outcomes and completion criteria. This paper provides a simple approach for presenting closure visualisation. It also recommends the use of watermarks containing the date and a visual cue indicating the maturity of the inputs on visualisations to improve transparency.

We conclude by recommending four areas for future research:

- stakeholder and proponent experiences, expectations, assumptions and concerns regarding closure visualisations
- evaluation of the current use and accuracy of closure visualisations (including superseded yet still publicly available information) at different stages of the mine life cycle
- assessment of data sources (factual and subjective) used to construct, inform and illustrate the closure visualisation
- establishment of closure visualisation protocols when presenting closure imagery or using visualisation tools (e.g. virtual or augmented reality) to communicate closure outcomes.

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References

BHP Billiton Iron Ore 2005, *Orebody 25 Decommissioning and Rehabilitation Plan*, https://www.epa.wa.gov.au/sites/default/files/PER_documentation/Appendix%20B.pdf

Brian J O'Brien & Associates 1992, *Marandoo Iron Ore Mine and Central Pilbara Railway, Environmental Review and Management Programme*, Hamersley Iron Pty Limited, Perth, https://www.epa.wa.gov.au/sites/default/files/PER_documentation/A0599_R0643_ERMP.pdf

Charles Darwin University 2022, *Researcher Using 3D Modelling to Help with Ranger Uranium Mine Site Cleanup in Kakadu*, https://www.cdu.edu.au/news/researcher-using-3d-modelling-help-ranger-uranium-mine-mine-site-cleanup-kakadu

Craig, L 2023, *AI Watermarking*, viewed 22 June 2024, https://www.techtarget.com/searchenterpriseai/definition/AI-watermarking

CSIRO 2023, *Enabling Mine Closure and Transitions: Opportunities for Australian Industry*, CRC TiME and CSIRO.

DES 2023, *Guideline Progressive Rehabilitation and Closure Plans (PRC Plans)*.

DITR 2009, *Community Engagement and Development, Leading Practice Sustainable Development Program for the Mining Industry*.

DMIRS 2020, *Mine Closure Plan Guidance - How to Prepare in Accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans*.

Glencore 2014, *Glencore Mine Rehabilitation: A Story of Mining Rehabilitation at our Westside Coal Mines in NSW*, https://www.youtube.com/watch?v=2qZSy6TR8iE

Grant, C, Loch, R, McCaffrey, N, Anstee, S & Doley, D 2016, *Mine Rehabilitation: Leading Practice Sustainable Development Program for the Mining Industry*.

ICMM 2019, *Integrated Mine Closure: Good Practice Guide*, 2nd edn.

ICMM 2022, *Closure Maturity Framework: Tools for Closure User Guide*.

ICMM 2023, *Mining Principles - Performance Expectations*.

Kragt, ME, Manero, A, Hawkins, J & Lison, C 2019, *A Review of Mine Rehabilitation Condition Setting in Western Australia*, The Western Australian Biodiversity Science Institute, Perth.

Landform Design Institute 2021, *Mining With the End in Mind: Landform Design for Sustainable Mining*, http://landformdesign.ca/LDI-PositionPaper2021.pdf

Pettit, CJ, Ryamond, CM, Bryan, BA & Lewis, H 2011, 'Identifying strengths and weaknesses of landscape visualisation for effective communication of future alternatives', *Landscape and Urban Planning*, vol. 100, no. 3, pp. 231–241, https://doi.org/10.1016/j.landurbplan.2011.01.001

Resources Regulator 2024, *Mine Planning and Rehabilitation Advice*, viewed 8 June 2024, https://www.resourcesregulator.nsw.gov.au/rehabilitation/mine-rehabilitation/mine-planning-and-rehabilitation-advice

Samaei, M, Stothard, P, Shirani Faradonbeh, R, Topal, E & Jang, H 2024, 'Mine closure surveillance and feasibility of UAV–AI–MR technology: a review study', *Minerals*, vol. 14, no. 110, https://doi.org/10.3390/min14010110