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Monitoring with purpose: linking rehabilitation performance to completion criteria

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Abstract

An assessment of rehabilitation performance requires a monitoring program aligned with agreed completion criteria and the collection of temporal data that meaningfully demonstrates progress toward closure objectives. In practice, rehabilitation monitoring is often implemented as a compliance-driven exercise, resulting in datasets that are poorly suited to evaluating whether completion criteria have been met or if the rehabilitation works have been successful. Typically, this is repeated over time, resulting in large datasets that are not tailored to demonstrating whether rehabilitation performance targets have been met. This paper presents a structured approach for aligning rehabilitation monitoring programs with completion criteria to improve transparency, efficiency and confidence in demonstrating that completion criteria have been met. Rehabilitation monitoring discussed in this paper applies to landform monitoring specifically, including the assessment of vegetation, erosion, landform geometry and fauna.

The approach begins with setting clear closure objectives and completion criteria that describe measurable attributes; explicitly linking each completion criterion to a monitoring program which can be used to test whether rehabilitation is tracking towards meeting the completion criteria. Monitoring methods should be selected based on their ability to detect change at spatial and temporal scales relevant to landform stability, vegetation establishment, ecosystem function and post-mining land use.

A case study is used to demonstrate how aligned monitoring programs can reduce regulatory uncertainty, streamline reporting, avoid unnecessary and costly monitoring, and aid in measuring the trajectory of performance towards meeting completion criteria. This also allows for early intervention and remediation activities, when rehabilitation performance might not be progressing as expected. The paper further outlines how ongoing data collection can be integrated into monitoring frameworks to support adaptive management. Importantly, the suggested approach avoids excessive monitoring and wasted resources while ensuring sufficient data quality and quantity to demonstrate the achievement of completion criteria, stakeholder alignment on what constitutes success and, ultimately, relinquishment.

Keywords: *completion criteria, rehabilitation monitoring, rehabilitation performance*

1 Introduction

Demonstrating that rehabilitation has achieved agreed closure objectives and completion criteria is a critical requirement for mine closure and relinquishment. Underpinning this process is the collection of monitoring data that can objectively demonstrate whether rehabilitation performance is progressing towards defined completion criteria. Stakeholders increasingly expect the narrative of rehabilitation performance to be demonstrated through transparent, robust and defensible monitoring programs that validate both short-term progress and the long-term achievement of post-mining land use.

In practice, however, rehabilitation monitoring programs are frequently implemented as a compliance-driven exercise rather than as a tool for performance evaluation and informed decision-making [Blommerde et al.

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2015; Department of Mines, Petroleum and Exploration (DMPE) 2026]. Monitoring indicators are often selected based on historical precedence, regulatory habit or ease of collection rather than their relevance to completion criteria (Spain et al. 2023). As a result, large volumes of data may be collected over many years without providing clear evidence that rehabilitation is on a trajectory towards meeting completion criteria. This misalignment can increase uncertainty for stakeholders, inflate monitoring costs, delay the identification of issues, extend monitoring time frames and undermine confidence in acheiving closure outcomes.

Despite extensive guidance and regulation, a recurring challenge is that proponents' completion criteria are too vague to indicate what needs to be achieved (Gimber & Shade 2024), while monitoring programs focus on measuring isolated attributes at inappropriate spatial or temporal scales. This disconnect limits the ability of monitoring data to demonstrate landform stability, vegetation establishment, ecosystem function or suitability for post-mining land use. In many cases, issues with rehabilitation performance are not identified or understood until late in the mine life, when opportunities for effective intervention are constrained, budgets are exhausted and closure risks have already escalated.

This paper presents a structured, purpose-built approach for aligning rehabilitation monitoring with completion criteria.

2 Guidance on rehabilitation monitoring practices

The International Council on Mining and Metals (ICMM) views rehabilitation monitoring as a core element of integrated mine closure, not a discrete end-of-life activity. ICMM emphasises that monitoring should be planned early, risk-based and implemented progressively throughout the mine life, with clear line-of-sight from closure objectives to measurable criteria. Monitoring programs are expected to demonstrate whether rehabilitation is tracking towards agreed post-closure land uses and environmental outcomes, and to inform adaptive management where performance deviates from expectations (ICMM 2025)

Published guidance requires rehabilitation monitoring to be objective driven, outcome focused and aligned with approved completion criteria (ICMM 2025). The DMPE Guidelines for Preparing Mine Closure Plans (the Guidelines) prescribe that proponents must define completion criteria for each closure domain and demonstrate, through ongoing monitoring, whether rehabilitation is trending towards those criteria over time (DMPE 2025).

For further information relating to the rehabilitation monitoring, the Guidelines refer to A framework for developing mine-site completion criteria in Western Australia, developed by the Western Australian Biodiversity Science Institute (Young et al. 2019). The WABSI framework establishes that monitoring programs should be designed around key risks such as landform instability, erosion, ecosystem failure or unacceptable post-closure land use outcomes, rather than broad or generic indicators (Young et al. 2019).

The WABSI framework states that rehabilitation monitoring is expected to:

- Test assumptions made during closure planning.
- Identify early signs of rehabilitation under-performance.
- Inform corrective or adaptive management where required.

A common feature of both pieces of Western Australian guidance is the linkage between monitoring parameters and completion criteria. Completion criteria are defined as agreed standards that indicate when rehabilitation has achieved an acceptable level of performance. Monitoring must therefore directly support the assessment of whether these standards have been met, rather than merely describing the condition of rehabilitation (DMPE 2025).

In Western Australia, regulators require rehabilitation monitoring results to be embedded in an adaptive management framework. Proponents are expected to review monitoring results regularly, update closure designs and completion criteria or implement management actions where outcomes deviate from expectations (DMPE 2025).

Although general principles of rehabilitation monitoring are acknowledged, there is little detailed guidance on designing a practical monitoring program (Manero et al. 2020). Monitoring frequency, duration and effort are unspecified; instead, adequacy is assessed by evidence strength, trend stability and risk so that closure decisions are based on performance rather than scheduled timelines.

3 Rehabilitation monitoring program

A sound rehabilitation monitoring program is founded on the development of clear closure objectives and measurable completion criteria. This enables the identification of key monitoring attributes and tasks, as well as systematic data collection. The collected data should be evaluated against the established criteria and subsequently used to refine and update those criteria as necessary. Each of these steps is defined in the following sections.

3.1 Set closure objectives and completion criteria

Closure objectives and completion criteria should be developed through a structured risk-based process to ensure that they address the key threats to achieving a safe, stable and non-polluting post-mining land use. Each risk can be broadly classified into categories such as safety, surface water and vegetation, with a corresponding closure objective developed to address each risk.

The initial phase in developing a rehabilitation monitoring program involves linking closure objectives to well-defined metric-driven completion criteria. Closure objectives should be high level and describe the overall intent of the closure program. The closure objectives should then be supported by completion criteria that demonstrate rehabilitation performance, providing the measurable basis to confirm that closure objectives have been achieved (Young et al. 2019). Completion criteria should be based on a thorough understanding of the site's knowledge base and key closure risks, as well as careful consideration of stakeholder requirements, legal obligations and the intended post-mining land use.

Throughout the development process, completion criteria should be tested against practical considerations, including measurability, data availability, and the degree of control held by the proponent over the aspect being assessed. Ambiguous or qualitative terminology should be avoided unless explicitly defined, and criteria need to be structured to enable a clear demonstration of attainment. The development process should also recognise the need for adaptability, allowing completion criteria to be updated to reflect improvements in monitoring methodologies and technologies, advances in technical understanding and changes in regulatory guidance.

Completion criteria that include a combination of leading and lagging indicators are often preferred. Leading completion criteria focus on components relating to landform designs, management actions and construction activities that can be assessed once rehabilitation activities are complete (Young et al. 2019).

Lagging completion criteria are those that are measured at the later stages of rehabilitation development and are typically required by regulators to provide evidence that final performance targets have been achieved (Young et al. 2019). Examples of lagging completion criteria include vegetation cover and species richness metrics or erosion data.

Consideration should be given to both leading and lagging completion criteria to ensure they provide a transparent, defensible and auditable framework to demonstrate rehabilitation performance, support ongoing regulatory engagement and build confidence in demonstrating the achievement of the closure criteria (Young et al. 2019; ICMM 2020).

Completion criteria should be specific, measurable, achievable, relevant and time-bound (SMART), ensuring they are clearly defined, practically achievable and supported by measurable outcomes within a defined time frame (DMPE 2025). Completion criteria can often be supported by performance standards, which aid in reinforcing the measurable nature of the completion criterion.

3.2 Specify key attributes

After developing completion criteria it is essential to clearly define how they will be measured. If a completion criterion cannot be measured with a practical method it should be revised. Table 1 outlines commonly recognised completion criteria and associated measurable attributes applied in Western Australian rehabilitation projects to demonstrate the attainment of those criteria.

Table 1 Typical completion criteria examples and commonly measured rehabilitation performance parameters

Aspect	Typical completion criteria wording examples	Commonly measured attributes
Vegetation	Native perennial plant cover on rehabilitated areas is ≥ X% of the reference site	Native perennial plant cover (%)
	Native perennial species richness on rehabilitation areas is ≥ X% of the reference site	Species richness
	Weed cover is ≤ X%	Weed cover
	Weeds of National Significance (WONS) are absent.	Presence of WONS
Landform geometry	Landform slopes conform to the approved design	Batter slope angle
	Final landform geometry conforms to approved closure designs	Surface elevation
Erosion	Gully features are minor, stable and within acceptable limits	Gully depth, length, width and volume
	Crest controls are intact and functioning as designed	Crest bund integrity
Fauna	Rehabilitated areas support use by native fauna	Fauna evidence (tracks, scats, activity)

3.3 Collect data

Once key attributes are known, a process for collecting data and the frequency of associated monitoring should be determined. Commonly accepted rehabilitation monitoring techniques and their associated pros and cons are described in Table 2.

While the use of techniques such as multispectral remote sensing and lidar is becoming more commonplace in rehabilitation monitoring, the limitations of these types of data need to be understood. Ground truthing should be undertaken routinely to complement remote sensing (if selected) (King & Clark 2000).

Table 2 Pros and cons of commonly accepted rehabilitation monitoring methods

Aspect	Attributes to be monitored	Methods	Pro	Con
Vegetation	Native perennial plant cover (%) Species richness Weed cover Presence of Weeds of National Significance	Multispectral remote sensing	Provides whole of landform data Can be very accurate at the correct resolution Repeatable to understand temporal changes Cost effective	Multispectral remote sensing cannot accurately distinguish the differences between perennial, annual and weed cover Multispectral remote sensing cannot detect plants in senescence or dormant phases Identification of vegetation to the species level isn’t always accurate
		On-ground transect or quadrat survey	Simple method. Can be used to capture species level information Established and widely accepted	Labour-, time- and cost-intensive Open to interpretation Limited spatial representativeness Can be subject to observer bias Traversing rehabilitation areas may be unsafe
Landform geometry	Batter slope angle Surface elevation	Lidar and high-resolution photogrammetry	Can be used to develop accurate digital elevation models that allow precise measurements of landform geometry Provides whole of landform data Can be directly compared to design surfaces Repeatable to understand temporal changes	Data can be influenced by vegetation Costs and data processing requirements can be high Data is sensitive to survey design and quality control Data volumes can be high

Aspect	Attributes to be monitored	Methods	Pro	Con
Erosion	Gully depth, width and volume Crest bund integrity	Lidar and high-resolution photogrammetry	Can be used to develop accurate digital elevation models that allow precise and quantitative measurements of gully metrics Can be used for early detection of areas of convergence Provides whole of landform data Can be directly compared to design surfaces Repeatable to understand temporal changes Accurately measures change over time	Data can be influenced by vegetation Costs and data processing requirements can be high Data is sensitive to survey design and quality control Data volumes can be high
		Targeted field inspections	Direct observations of erosion processes can be made An assessment of the soil and surface condition can be observed Low equipment cost Credible method Useful for small, isolated areas	Limited spatial coverage and representativeness Can be open to observer bias Increased foot traffic can result in more erosion Is impractical for estimating total erosion volumes Access to rehabilitation areas may be unsafe
Fauna	Fauna evidence (tracks, scats, activity)	Opportunistic fauna observations	Cost effective Easy to implement Demonstrates active fauna usage Complements other monitoring methods	Uneven spatial coverage Does not provide quantitative data

While remote sensing techniques, such as multispectral or lidar monitoring, enable comprehensive assessment at the landform scale, current guidance does not mandate the specific number or frequency of on-ground monitoring locations; instead it emphasises that on-ground monitoring sites should be sufficient to capture variability and demonstrate compliance with completion criteria. For meaningful comparison and statistical analysis, it is recommended to target between 3 and 5 monitoring sites per homogenous rehabilitation area. In larger areas or where variation exists, additional monitoring sites may be necessary to ensure thorough evaluation (DMPE 2025).

Both on-ground monitoring and remote sensing should be conducted across rehabilitated areas as well as selected representative analogue sites. This approach allows for the evaluation of additional factors which may influence success, such as climate conditions, drought, fire, flood and the landscape's response to these factors. When selecting an analogue monitoring site it is important to ensure that it is:

- ecologically appropriate within the local area
- representative of post-mining land use
- unaffected by mining-related disturbances
- stable and capable of self-sustenance
- accessible and suitable for repeated monitoring activities.

The frequency of rehabilitation monitoring should be based on risk, with emphasis given to early in the first few years of post-rehabilitation activities (Hooper et al 2016). In this phase, rehabilitation monitoring is required at least annually for early detection of threats to rehabilitation success (DMPE 2021). While erosion monitoring and conformance to design type monitoring should occur within the first year, vegetation monitoring shouldn't commence until year 2 post-closure works to allow time for vegetation growth and development. Assuming vegetation performance is progressing as expected, the monitoring frequency can be reduced (i.e. biennial) after the initial 5 years of monitoring, or on an event basis (i.e. large rainfall events or prolonged drought).

3.4 Review data

Reviewing collected data is a critical step in any monitoring program. Where data are collected by a third party, raw datasets should be requested and examined to identify and query potential outliers. Remote sensing outputs, including those generated using deep learning tools, can contain errors if not carefully checked and should be validated through on-ground assessment.

Rehabilitation monitoring data provide an important evidence base for assessing whether landforms and ecosystems are progressing along expected recovery trajectories towards defined completion criteria. By establishing baseline conditions soon after rehabilitation works are completed and tracking indicators such as vegetation cover, species richness and erosion stability across multiple datasets, performance can be assessed against predicted trajectories. This analysis helps determine whether rehabilitation is improving, stabilising or declining, and whether the rate of change is sufficient to meet closure criteria within acceptable time frames. Analysing temporal datasets also supports early detection of divergence from the desired trajectory, enabling timely adaptive management responses.

Comparing rehabilitation monitoring data against leading completion criteria is important for evaluating rehabilitation performance and demonstrating progress toward relinquishment. While completion criteria define the agreed conditions under which closure outcomes are considered to have been met, monitoring data in isolation only describes site conditions. Explicitly assessing monitoring results against completion criteria enables a performance-based evaluation and an assessment of whether rehabilitation is moving towards agreed closure outcomes. This comparison allows trends to be interpreted in the context of closure performance, supports early identification of underperformance and can lead to more proactive adaptive management.

Establishing comprehensive completion criteria, as outlined in this paper, supported by appropriate monitoring to verify achievement, enhances the efficiency of monitoring efforts and minimises unnecessary data collection that does not contribute to closure decision-making. It also allows early cost-efficient remedial intervention if required.

If the monitoring data does not indicate progress towards meeting completion criteria, intervention may be necessary, the rehabilitation methods may require improvement or the completion criteria are unattainable. If intervention is deemed warranted (i.e. results indicate little improvement and are well below completion criteria), further monitoring and investigation should be undertaken. Rehabilitation performance issues are usually a result of excessive erosion, poor quality growth media, weed dominance, unsuitable soil chemistry or inadequate surface water controls. Should investigations reveal no such issues, and the rehabilitation area is not meeting the existing completion criteria, review and adjustment of the completion criteria may be required.

3.5 Update and refine completion criteria

While closure objectives should be fixed, completion criteria should be regarded as transitional values rather than fixed end points. They require continuous refinement and updating as new rehabilitation monitoring data becomes available, and regular reassessment to ensure their ongoing relevance. Typically established many years before closure, completion criteria may be impacted by changes to the mine plan and changes in the natural environment over time. In most projects, completion criteria are formulated during the project approval phase, often relying on limited baseline data and predictive models.

The enhancement and refinement of closure criteria with comprehensive rehabilitation monitoring data will lead to more effective and rigorous completion criteria. Review of criteria should be completed on a regular basis as monitoring data become available.

4 Case study

A practical application of this rehabilitation monitoring process was demonstrated at a mine site in the Pilbara region of Western Australia, utilising erosion data. Rehabilitation activities on the waste rock landforms (WRLs), including reprofiling, establishment of crest bunds, application of topsoil and seed, and deep ripping on the contour, were completed in 2017. The process for establishing the rehabilitation monitoring program for assessing erosion on rehabilitated landforms at the mine site is presented in the following sections.

4.1 Setting closure objectives and completion criteria

The closure risk assessment undertaken for the landforms domain identified uncontrolled drainage on and around the landforms as one of the highest closure risks. Accordingly, a surface water closure objective was established that described the intent of closure as minimising uncontrolled surface water flows and associated impacts. The completion criteria developed during the early stages of the mine life required landforms to be constructed in accordance with an approved design and for erosion levels to demonstrate stabilisation. This case study considers the rehabilitation monitoring program implemented to evaluate whether erosion levels had stabilised.

4.2 Selection of key attributes

The key attributes identified for the completion criterion that erosion levels had stabilised related to measuring erosion features including gully depth, length, width and volume over a defined period. Since 2018, annual erosion monitoring across 4 WRLs was completed using orthophotography and a lidar-derived digital elevation model (DEM) analysis, complemented by on-ground field observations.

4.3 Data collection

The lidar data was processed and classified to produce a bare earth DEM of the ground surface. Vegetation was excluded (as far as practicable) to minimise the impact of vegetation height in the DEM on gully measurements. All discernible gullies were identified, and their respective volumes and dimensions were calculated. These values were then averaged per hectare of batter slope for each WRL to enable comparative analysis between the WRLs.

4.4 Data review

The data for each WRL are illustrated in Figure 1.

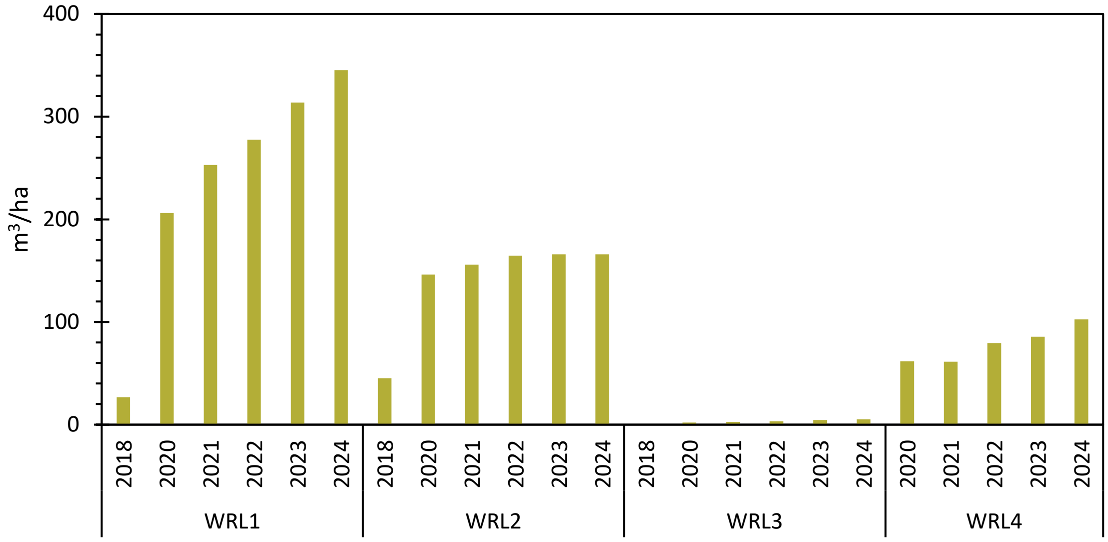

Figure 1 Gully volume per hectare for each of the waste rock landforms (WRLs) since 2018

The information provided valuable insights into each of the WRLs (Figure 1):

- WRL1 – Gully volumes were high and have continued to increase over time. The challenging location of the WRL and growth of a considerable vegetation community that would be destroyed by remedial works, coupled with steep natural topography, has meant that remedial works would be difficult to conduct and a decision was made to continue with the monitoring program to determine if the rate of erosion would stabilise over time. Following the collection of data in 2024, and the continued increasing trend in gully volume, remediation and repair of erosion features were scheduled, though these activities have yet to commence.
- WRL2 – Gully volumes were moderate, with a considerable increase observed soon after rehabilitation works were completed (i.e. between 2018 and 2020) and an upward trend in gully volume noted. Based on the data collected up until 2022 enhancements to crest bunds and backslope areas were recommended to manage surface water flow. These recommendations were implemented in 2022 to direct surface water away from the slopes. Subsequently, after 2022, gully volumes exhibited a stabilising trend (i.e. the rate of change between monitoring events was minimal) despite above average rainfall, and no further deterioration was noted. It should be noted that no gully repairs were performed during recommended remedial works.
- WRL3 – Gully volumes were minimal, with minor erosion noted at this WRL, and erosion performance was considered excellent.
- WRL4 – Gully volumes were low and have varied over time, while erosion was minimal but had not stabilised.

Data from WRL2, 3 and 4 were compiled to develop an expected performance trajectory, expressed as average annual gully volume across the landforms at this mine site (Figure 2). This trajectory can inform future decisions about underperforming landforms and indicate when intervention or remediation may be required.

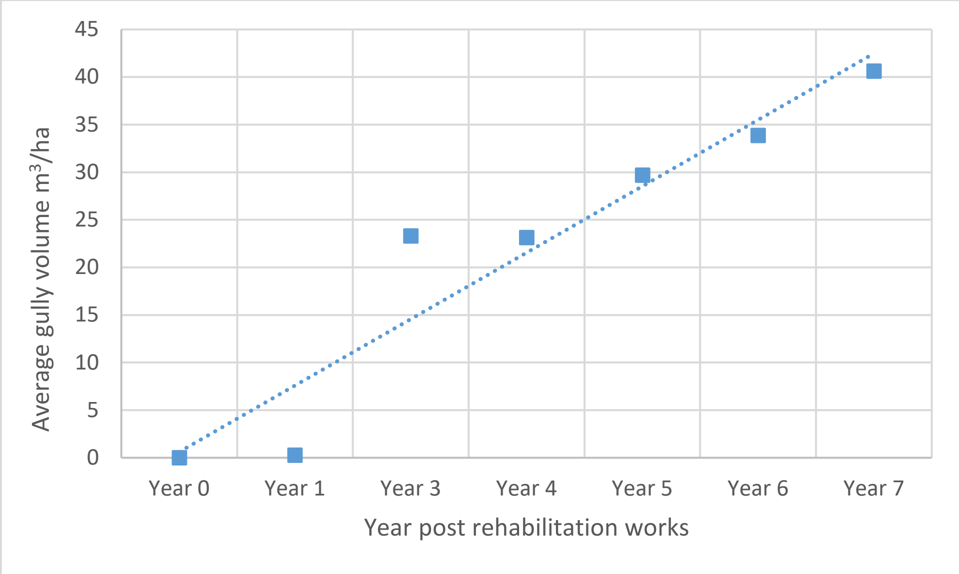

Figure 2 Average gully volume (m^3) per hectare for waste rock landforms 2–4, based on year post-rehabilitation works

In this particular instance, although the completion criteria stipulated that erosion levels were to stabilise, the performance standard had not been defined, and it was the intent of this monitoring program to inform the performance standard using the data collected. Due to underperformance and the need for remediation at WRL1, this data was excluded from establishing the performance standard. Instead, information from WRL2, 3 and 4 was used to calculate an average 3-year rate of change of 13 m^3/ha. As the rate of change at WRL4 had not yet stabilised, and this may have been skewing the data, the performance standard indicating stabilisation of erosion was reviewed and set at a 10 m^3/ha average over a 3-year period.

4.5 Refinement of completion criteria

Since the development of the performance standard from the 2018 to 2024 dataset, the completion criteria were reviewed by the DMPE in the site's mine closure plan. Further refinement of the performance standard was requested. In response, additional data was collected in 2026 (as yet unpublished), and the performance standard is likely to drop to 8 m^3 following further feedback and additional data analysis.

5 Conclusion

This paper outlined the importance of developing metric-driven and robust rehabilitation monitoring programs that are aligned with completion criteria to ensure mine closure outcomes are transparent, efficient and defensible. Drawing on both Western Australian and international guidelines, the approach emphasises outcome-driven monitoring, adaptive management and evidence-based decision-making. By setting measurable completion criteria, specifying key attributes, and applying robust monitoring methods including spatially explicit and repeatable metrics like vegetation cover and erosion volume, monitoring programs can reliably track progress and trigger timely interventions where needed.

The case study from the Pilbara demonstrates how aligned monitoring, underpinned by technologies such as lidar-captured data, can inform remediation strategies and provide clear evidence for closure decisions. This structured approach not only supports regulatory compliance but also ensures ongoing improvement and stakeholder confidence through transparent reporting and adaptive management.

Ultimately, successful mine closure hinges on the integration of quantitative, spatially representative and risk-based monitoring with well-defined completion criteria. This enables proponents to demonstrate the achievement of closure outcomes, respond proactively to underperformance and deliver successful rehabilitation outcomes.

References

Blommerde, M, Raval, S, Roslyn, T 2015, 'Assessment of rehabilitation completion criteria for mine closure evaluation', *Conference for Sustainable Development in the Minerals Industry*, Vancouver.

DMPE 2021, *Mine Closure Completion Guideline – For Demonstrating Completion of Mine Closure in Accordance with an Approved Mine Closure Plan*, Government of Western Australia.

DMPE 2026, *Environmental Reporting Guideline*, Government of Western Australia.

DMPE 2025, Guideline for Preparing Mine Closure Plans, Government of Western Australia.

Gimber, C & Shade, N 2024, 'Completion criteria: the tension between certainty and flexibility', in AB Fourie, M Tibbett & G Boggs (eds), *Mine Closure 2024: Proceedings of the 17th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 1261–1268, https://doi.org/10.36487/ACG_repo/2415_91

Hooper, M, Glomb, S, Harper, D, Hoelzle, T, McIntosh, L & Mulligan, D 2016 'Integrated risk and recovery monitoring of ecosystem restorations on contaminated sites', *Integrated Environmental Assessment and Management*, vol. 12, issue 2, pp. 284–295.

International Council on Mining and Metals (ICMM) 2020, *Key Performance Indicators: Tool for closure*, London.

International Council on Mining and Metals (ICMM) 2025, *Integrated Mine Closure: Good Practice Guide*, 3rd edn, London.

King, T & Clark, R 2000, 'Verification of remotely sensed data,' in F Kuehn, TVV King, B Hoerig & DC Peters (eds), *Remote Sensing for Site Characterization: Methods in Environmental Geology*, Springer, Berlin.

Manero, A, Kragt, M, Standish, R, Miller, B, Jasper, D, Boggs, G & Young, R 2020. 'A Framework for Developing Completion Criteria for Mine Closure and Rehabilitation', *Journal of Environmental Management*, vol. 273, pp. 1–10.

Spain, CS, Jones, JL, Nuske, SJ & Robinson, D 2023, 'The use of analogue sites for native ecosystem mine rehabilitation—a case study incorporating effective approaches for selection, monitoring and analysis', in B Abbasi, J Parshley, A Fourie & M Tibbett (eds), *Mine Closure 2023: Proceedings of the 16th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, https://doi.org/10.36487/ACG_repo/2315_080

Young, R, Manero, A, Miller, B, Kragt, M, Standish, R, Jasper, D & Boggs, G 2019, *A Framework for Developing Mine-Site Completion Criteria in Western Australia*, The Western Australian Biodiversity Science Institute, Perth.