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Navigating divergent expectations: completion criteria challenges in the Pilbara, Western Australia

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Abstract

Completion criteria in the mining industry have been a topic of significant discussion over the past decade, with numerous frameworks proposed for their development. However, setting satisfactory criteria remains challenging due to divergent interests among key stakeholders, including Traditional Owners, industry and regulatory bodies. Traditional Owners face cultural risks such as restricted land access, while regulators are concerned about the residual impacts of mines under care and maintenance. Industry stakeholders grapple with ongoing maintenance costs and challenges in closure strategy selection and site relinquishment.

In Western Australia, legal requirements dictate that Indigenous people's rights must be respected for site relinquishment, necessitating the inclusion of native title rights in setting cultural completion criteria. Despite this, reaching a compromise between Traditional Owners, regulators and industry stakeholders to establish satisfactory completion criteria remains difficult, leading to delays in major capital projects and jeopardising successful site relinquishment.

Regional mine closure planning is proposed as a holistic approach to address these challenges, as solutions are more economically viable at a regional scale and can mitigate issues that cannot be resolved on a site-by-site basis alone. Additionally, the implementation of a restoration economy at a regional level could incentivise adequate mine rehabilitation to meet cultural completion criteria. This collaborative approach aims to facilitate successful mine closure while respecting cultural and environmental considerations.

Keywords: *completion criteria, stakeholders, Traditional Owners, site relinquishment, regional mine closure planning*

1 Introduction

The importance of setting specific, measurable, achievable, relevant and time-bound (SMART) completion criteria in mine closure planning has grown significantly in recent decades, driven by increased regulatory requirements and stakeholder expectations for environmental sustainability and social responsibility. The challenges in establishing and reaching a consensus on completion criteria are among the most significant, if not the greatest, obstacles in preventing the relinquishment of closed mine sites (Butler & Bentel 2011). Over the past two decades, there has been a significant global shift towards more stringent environmental regulations (Franken & Schütte 2022), which has emphasised the need for clear, measurable outcomes in mine closure to ensure that mining activities do not leave a lasting negative impact on the environment and society (International Council on Mining and Metals [ICMM] 2019; Getty & Morrison-Saunders 2019). The mining industry has increasingly adopted sustainability goals (Franken & Schütte 2022), integrating environmental, social and governance criteria into operational and closure planning processes. Communities, investors and non-governmental organisations have exerted pressure on mining companies to provide transparency and accountability in their closure plans, and to consider closure impacts and their mitigation prior to starting operations (Brock 2021). These shifts in requirements have

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collectively reinforced the need to develop SMART completion criteria to enable a mine to assess whether it is trending towards successful relinquishment and to prove this once it has been achieved.

In Western Australia, the use of SMART completion criteria is mandated in mine closure planning under the *Mining Act 1978* (Western Australia 1978) and associated guidelines. The Statutory Guidelines for Mine Closure Plans by the Department of Mines, Industry Regulation and Safety (DMIRS 2023) stipulate that mine closure plans must include clear, measurable criteria to demonstrate successful rehabilitation and closure. This ensures that environmental and social impacts are adequately addressed, and that the site can be relinquished safely and responsibly. In support of the DMIRS Guidelines, the Western Australian Biodiversity Science Institute (WABSI) provides comprehensive guidance for setting SMART completion criteria in mine closure planning (Young et al. 2019). These latter guidelines provide a framework designed to help mining companies develop effective and achievable rehabilitation goals, ensuring that post-mining land is suitable for its next intended use, and emphasise the importance of creating site-specific completion criteria that are informed by scientific research and stakeholder perspectives. This approach involves detailed monitoring and risk assessment to ensure that the rehabilitation efforts are successful and sustainable over the long term.

Despite these guidelines, and the existence of multiple alternative frameworks for the development of SMART completion criteria (Edwards et al. 2022; Iles 2022; Manero et al. 2020; Coppin 2013), the process for setting these criteria remains challenging. This is due to divergent drivers for mine closure from key stakeholders, including Traditional Owners, industry and regulatory bodies. Traditional Owners are focused on a re-entry strategy that provides safe access and traditional use (Smith 2009), industry is focused on a cost-effective exit strategy, and regulators are concerned about protecting the public and the environment while avoiding future liability for taxpayers. Furthermore, there is a global trend of completion criteria being ambiguous or inadequately defined (Young et al. 2019). This lack of specificity results in unclear standards for regulatory authorities and fosters unrealistic expectations among stakeholder groups (Holmes et al. 2015). This paper explores these challenges and recommends potential solutions to navigate these divergent expectations when developing SMART completion criteria for closure.

2 Challenges in setting completion criteria

The main function of completion criteria is to assess whether a desired end state has been achieved to facilitate site relinquishment. The desired end state is defined by the goals, objectives and outcomes, agreed between stakeholders, to achieve at closure (Fawcett & Laurencont 2019). Failing & Gregory (2003) found that the goals set for an environmental resource, whether for stakeholders' demands for spiritual wellbeing, aesthetic pleasure, food supply or other outcomes, greatly influence management methods and success criteria, which emphasises the significance of the influence of the desired end state on management approaches and criteria for success. Consequently, the lack of explicit end state definition can lead to suboptimal decisions and mine closure results. The desired end state should encapsulate the values of relevant stakeholders, including Traditional Owners, regulators and the industry. Given the diverse motivations that shape each group's desired end state, formulating a comprehensive closure vision that accommodates these varied perspectives presents a significant challenge.

In Western Australia, legal requirements under the *Native Title Act 1993* (Government of Western Australia 1993) dictate that Indigenous people's rights must be respected when considering site relinquishment options, necessitating the consideration of native title rights in setting SMART completion criteria. This can result in opposing end state values for closure where Traditional Owners desire access to their land and the regulator mandates that access to unsafe areas is restricted. A typical example is the legal obligation for mines to construct abandonment bunds around pits where backfill is not to natural ground level (Department of Industry and Resources 1997), which may prevent Traditional Owners from accessing heritage sites in instances where these sites are within the zone of instability. Reaching a compromise between the desired end state value of Traditional Owners, regulators and industry stakeholders to establish satisfactory completion criteria can result in schedule delays to major capital projects set for closure and may jeopardise successful site relinquishment. Obtaining end state values from Traditional Owners can also be challenging due to their limited availability and the number of operational issues that take priority for discussion by the industry. It is essential, however, that Traditional Owners provide their end state values, since the detail required to address cultural aspects can only be obtained through the involvement of the Aboriginal landowners who are the creators and the owners of the cultural landscape (Smith 2009).

The challenges in developing SMART completion criteria are further compounded by making category mistakes which are the result of conflating values, processes and properties (definitions of these terms by Wallace & Jago [2017] are provided in Table 1), and assigning them to an incorrect category. If goals are conflated with properties such as sustainability or environmental health rather than being described in terms of a desired end state (i.e. the ultimate outcomes that people care about), then confusion is likely to result (Wallace & Jago 2017). Effective planning and decisions depend on avoiding these category mistakes, especially since values describe the ultimate outcome of management (Wallace & Jago 2017).

Table 1 Definitions of key terms for categories used in developing an ontological framework (from Wallace & Jago 2017)

Term	Definition
Category mistake	'…the placing of an entity in the wrong category' or the 'attribution to an entity of a property which that entity cannot have' (Meiland 1999)
Elements	the concrete entities in a system, including water, rocks, mountains, roads, buildings and organisms
Processes	the interactions (including actions, reactions and operations) among and within elements that lead to a state change
Properties	the ways things are as the entities represented by descriptions of elements, processes, systems or values
State	a specific way things are, involving one or more element, process, system or value, plus one or more of their properties
System	a unit formed by all the elements of a defined space and time, including the processes occurring within and among them
Values (end state values)	enduring beliefs concerning the preferred end states of human existence, including those required for survival and reproductive success which, taken together, determine human wellbeing
Values (principles)	enduring beliefs concerning the preferred ethical properties of human behaviour that instrumentally contribute to human wellbeing

Completion criteria are indicators and targets, which are all properties, and closure criteria describe the properties of the post-closure condition that meets the end state values. It is therefore easy to make category mistakes which result in confusion and difficulty for identifying metrics to prove completion criteria are being met, and uncertainty as to whether meeting these metrics will indeed result in the desired end state being met. Furthermore, directly mixing ends and means in analyses generates category mistakes (Wallace & Jago 2017), which can often happen in developing SMART completion criteria where a value (i.e. a closure objective or outcome) can be misconstrued as a property and vice versa.

Examples of category mistakes made in setting completion criteria are found in Coppin (2013), who provides 'Factors and indicators for criteria (Vegetation)', as presented in Table 2. These 'are presented as proposed success criteria (i.e. completion criteria) that might be selected and applied. Here the 'Criteria type' (i.e. Vegetation) is reflective of an element. The 'Criteria group' represents properties of the element (i.e. ground cover, species present and biodiversity). The criteria (i.e. 'Factors and Indicators') proposed for ground cover are properties (i.e. density, percentage cover, layers and canopy structure) but are lacking indicators and targets which are reflective of the desired end state for these properties. The completion criteria developed for species present include a mix of properties, states and methods, and also lack the inclusion of indicators and targets. The properties included are 'species presence/absence' and 'cover abundance', and the methods included are '…using Domain or similar scale and multivariate analysis'. The 'Presence of alien or invasive species' is considered a description of the state (defined as 'A specific way things are, involving one or more element, process, system, or value, plus one or more of their properties' in Table 1). The completion criteria for biodiversity include properties (i.e. diversity and biodiversity value indices, naturalness, rarity/scarcity) but again these properties are not supported by indicators or targets. The 'Ability to support vulnerable or protected species' (Table 2) is again considered a description of the state and is not considered a completion criterion. This example illustrates how a typical completion criteria set often excludes examples of indicators and targets that are required to achieve a specific end state, and are often mixed with methods and states instead of only including properties and the associated indicators and targets required for those properties.

Table 2 Example of category mistakes made in developing SMART completion criteria (Coppin 2013)

Criteria type	Criteria group	Factors and indicators for criteria
Vegetation	Ground cover	Density and % cover — layers and canopy structure (herbaceous, shrub and tree)
	Species present	Species presence/absence — cover abundance using Domain or a similar scale. Potential to use multivariate analysis of the community type and relate it to recognised community classifications
		Presence of alien or invasive species
	Biodiversity	Indices such as diversity — biodiversity value based on diversity, naturalness and rarity/scarcity against recognised classifications. Can be referenced to modified, natural or critical habitat
		Ability to support vulnerable or protected species

Once SMART completion criteria have been developed in accordance with a well-defined desired end state, the final challenge is to ensure these criteria are achieved within a certain time frame. Mine closure planning is often undertaken using a 'silo mentality' which restricts the flow of regional knowledge between mines and can result in constraints to successful mine closure planning and, resultantly, the ability of a mine to achieve its completion criteria in a holistic and effective manner. The application of regional mine closure planning has the potential to address these constraints. While mines are constrained by the licences, permits and authorisations that govern their designated mining areas, it is common for large mining enterprises to span extensive territories or encompass multiple operations within a single region. These operations, often intermingled, share comparable challenges, effects and lingering risks. Such 'regional linkages' present a chance for concerted land use and mine closure strategies across broader landscapes, potentially alleviating the aggregate environmental and social repercussions through a unified approach. Additionally, they offer a platform for the holistic management and preservation of vulnerable social, ecological and economic communities that considers the bigger picture (Hattingh et al. 2019). As a result, regional mine closure planning has the potential to reduce mine closure risks and increase the probability of achieving the SMART completion criteria agreed to. Furthermore, to effectively mitigate potential future liabilities via mine site repurposing, a regional mine closure planning perspective is essential to guide common closure outcomes across multiple mines to achieve sustainable future land use and industry (Murphy et al. 2019).

3 Potential solutions to developing specific, measurable, achievable, relevant and time-bound (SMART) completion criteria

The solutions to mitigating the challenges identified in developing SMART completion criteria are multifaceted and include avoiding category mistakes, setting clear goals for closure that are based on shared end state values and the consideration of regional closure planning. These concepts are explored in the Sections that follow.

3.1 Avoid making category mistakes

To avoid making category mistakes it is necessary to develop an ontological framework, as described by Wallace & Jago (2017), for closure planning to reduce confusion in category allocation and promote consistency in developing SMART completion criteria. An ontology is a 'list of concepts and categories in a subject area that shows the relationships between them' (Oxford Learners Dictionary n.d.).

If professional planners are unclear concerning their ontological framework, this is likely to hinder communication and analysis. The ontological framework should be designed to reduce problems of ambiguity and confusion in planning (Wallace et al. 2022). The categories proposed for use in the ontological framework by Wallace & Jago (2017) cover the 'what' (elements, properties, states, systems), 'how' (processes) and 'why' (values) of management as defined in Table 1. Defining the categories of entities that exist within models and explaining their relationships through an ontological framework provides a foundation for exploring and comparing mental models and a sound basis for communication and analysis (Wallace et al. 2022).

A proposed ontological framework for mine closure planning is presented in Figure 1, which presents the ontological categories relevant to mine closure planning and decisions using the categories proposed by Wallace & Jago (2017). The desired end state values we are trying to achieve through the closure process must be identified to guide the development of SMART completion criteria, and to achieve this we need to elicit values from key stakeholders. As stated by Wallace et al. (2016) it is very important, particularly in multiple stakeholder situations, for all stakeholders to agree on the set of elements to be managed. This can be used as the basis for planning processes such as risk analysis and values elicitation. The ontological framework for mine closure defines these elements and supports the visioning of the desired end state. Once the desired end state values are known, SMART completion criteria will define the specific properties, including indicators and targets, required for the elements in the system. This process allows us to break down the elements identified to a level where we are able to establish appropriate and relevant completion criteria.

The issue of category mistakes is inferred by Poscente & Charette (2011), who found similar issues of ambiguity, debate and differential interpretation within the oil sands industry. In response, they developed a framework to define the criteria and indicators for achieving the desired end state. The framework breaks down the desired end state into goal, objective and completion criteria. Completion criteria are then further broken down into indicators, measures, methods, thresholds and standards. This breakdown of the end state into these parts provides a sound approach for avoiding category mistakes.

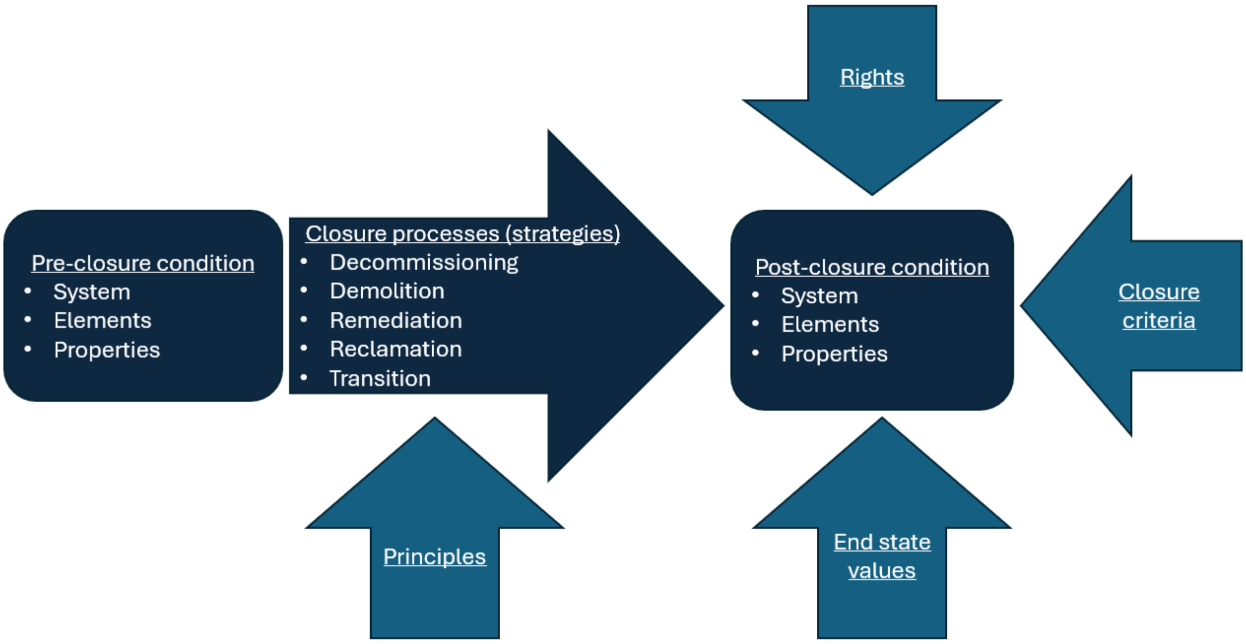

Figure 1 Ontological framework for mine closure planning

The ontological framework for mine closure planning presented in Figure 1 shows how a mine would progress from the pre-closure condition to the post-closure condition through a series of processes, or closure strategies. The pre- and post-closure conditions are considered states and comprise systems that include elements and properties. The closure processes are impacted by a set of principles which are applied to obtain the post-closure condition. This is driven by end state values and rights (for example, native title rights required for consideration in Western Australia). The closure criteria assess whether the properties of the post-closure condition meet the criteria (presented as indicators and targets) required to achieve the end state values. Closure criteria are defined as 'criteria developed within mine closure planning against which the performance of mine closure treatments are monitored, and against which successful mine closure is measured' (International Organization for Standardization [ISO] 2020).

3.2 Application of shared end state values in setting SMART completion criteria

The end goal for an environmental resource will strongly affect management strategies and measures of success. Therefore, inferior decisions may result when goals are not clearly specified (Wallace & Jago 2017). In this context, an environmental resource refers to an element (as defined in Table 1) that is being exploited or impacted upon by the operation of a mine site. Without a clear desired end state, SMART completion criteria are rendered redundant. The desired end state should address the values of the key stakeholders involved, including industry, regulators and Traditional Owners. Stakeholder is defined as 'person, group, or organization with the potential to affect, or be affected by, the process or outcome of mine closure and reclamation. It can include internal and external stakeholders such as the host community, regulators, non-government organizations, and other community groups, as well as future land users and investors' (ISO 2020). As discussed in Section 2, the divergent end state values of stakeholders make it challenging to identify a desired end state that addresses all stakeholder values. Potential solutions lie in unifying divergent drivers by considering shared end state values for closure. Closure objectives should be developed as a direct reflection of the desired end state values (i.e. closure vision) to be met at closure. An example of identifying shared end state values is presented in Figure 2, which shows end state values identified for each of the key stakeholders and then identifies potential shared end state values. The stakeholders and shared end state values included in Figure 2 are not exhaustive list and are included as an example of key stakeholders and potential shared end state values for a mine in Western Australia. In this example, the regulator should reflect the views of the broader community, including employees and contractors. The shared end state values are used as a starting point to develop SMART completion criteria that consider the perspective of the key stakeholders. Focusing on shared end state values to define the desired end sate (or closure vision) will result in meaningful SMART completion criteria that measure the success of achieving an end state that considers the perspectives of key stakeholders and consolidates divergent drivers for closure.

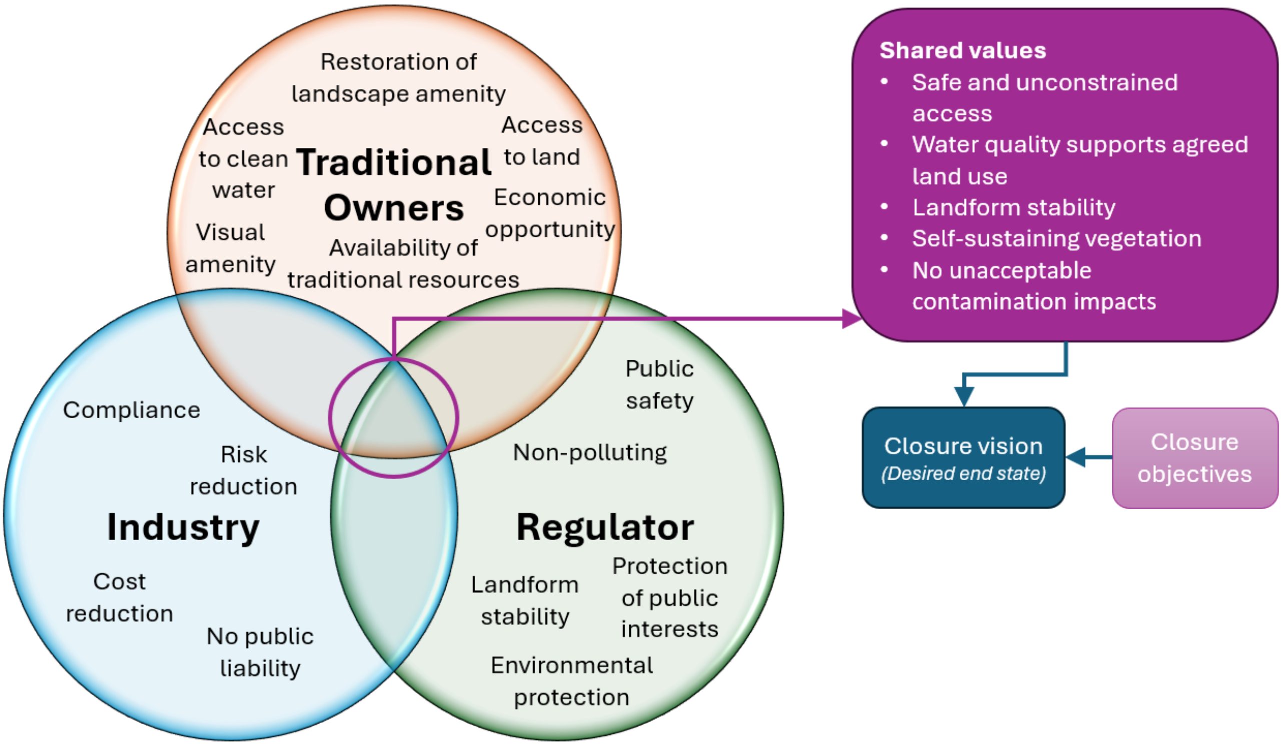

Figure 2 Identification of shared end state values for developing SMART completion criteria

This collaborative approach in developing SMART completion criteria is closely linked to the concept of collaborative design, or co-design. Co-design is a participatory strategy that involves designers and non-designers in a joint effort to develop innovative solutions, with designers facilitating the process to leverage the collective expertise and perspectives of all participants, particularly the end-users, for effective problem-solving (Interaction Design Foundation 2023). Co-design in the context of mining refers to an approach where various stakeholders, including miners, community members, environmental experts and government officials, work together to design mining projects and their associated processes. This method aims to harness the collective wisdom and insights of everyone involved, especially those directly affected by mining activities, to innovate and solve problems effectively. It involves actively engaging these stakeholders not only in setting the goals and objectives but also in the design, and sometimes the implementation, of the mining project.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO 2023) reports that a history of poor inclusion of partners and stakeholders in closure decision-making and implementation has led to a trust deficit between industry and communities. Creating and sustaining a constructive and ongoing dialogue between mining companies and community partners can help to build trust, encourage long-term collaboration and create shared value, while shaping mine closure activities through co-design, including post-mining land use, can help in meeting cultural expectations (CSIRO 2023). The application of co-design in mine closure planning has become highly desirable within the mining industry due to the potential the process has in addressing the needs of key stakeholders regarding closure (Wilson 2020). Co-design and the development of SMART completion criteria share the dual purpose of ensuring the outcomes of mine closure meet the needs of all stakeholders and that the post-mining land use is acceptable to the community. Therefore, collaborative development of SMART completion criteria using desired end state values of key stakeholders is a means to catalyse co-design in mine closure planning.

3.3 Regional mine closure planning

The application of regional mine closure planning has the potential to 'increase the overlap' of shared end state values. By removing the limitations that result from a single-site closure mentality formed on the basis of mine lease boundaries, a wider array of values can be incorporated. Iron ore mining in the Pilbara in Western Australia can be used as an example where the landform is characterised by large open pits with multiple waste rock dumps (WRDs) and tailings storage facilities (TSFs). Sites of cultural significance to Traditional Owners are interspersed across the site and some of these lie adjacent to pit walls and within the zone of instability (ZOI). Open pits are generally not backfilled to surface, but mines are typically mandated to backfill the pits above the returning groundwater level to allow for aquifer reinstatement and to avoid the formation of pit lakes (Dodman et al. 2013). Although WRD material is used to backfill the pits to the returning groundwater level, multiple WRDs often remain at closure. The WRD material is generally considered inert, although there are localised incidences of potentially acid-forming (PAF) material due to pockets of sulphidic lithologies in the pits (Bonstrom et al. 2012). The risk of contaminated seepage resulting from PAF material stored in WRDs is usually managed by encapsulating PAF with non-acid forming material to buffer the acidity with alkaline material.

Regional mine closure planning can address many of the end state values identified for each of the key stakeholders, as the following scenario illustrates.

This scenario entails reallocating all WRD material as backfill for the pits. Although initially cost intensive, this strategy may prove economically viable on a regional scale, particularly if executed during the operational phase using available pits from adjacent mines, thereby negating the creation of new WRDs. A similar approach could apply to TSFs by situating new facilities within mined-out pits, whether within the confines of the mine lease or in proximate mines with available pits. Depositing TSF material within mined-out pits instead of constructing new facilities would also increase the material volume available for backfilling pits to surface where possible. This strategy harbours the potential to catalyse a restoration economy, creating opportunities for Traditional Owner-operated contractor firms to carry out backfill activities. Affected aquifers and springs must be restored in post-closure mines, and often managed aquifer recharge (MAR) strategies are planned to fulfil this requirement. A common challenge for MAR initiatives is sourcing adequate water for reinjection. Regional mine closure planning could facilitate a collaborative approach among competing mines to manage water resources comprehensively, potentially providing source water for MAR schemes. Table 3 summarises the way this would address the end state values for stakeholders. The benefits of regional mine closure planning are, however, constrained by regulations and consultation requirements. Although obvious closure planning benefits would result from the ability to move material between multiple sites, this is currently restricted by mining regulations, and Traditional Owners would need to be consulted to gain consent for moving material and water within and between native title boundaries.

Table 3 Potential mechanisms of meeting values through regional mine closure planning

Stakeholder	End state values	Mechanisms of meeting values through regional mine closure planning
Industry	Compliance	Ensuring pits are backfilled above the recharging groundwater level to adhere to environmental regulations
	No public liability	Enhancing pit safety and stability through additional backfill, thereby reducing the zone of instability
	Risk reduction	Eliminating waste rock dumps to reduce the risk of cover failure and mitigating pit lake formation by backfilling pits to a higher level
	Cost reduction	Reducing costs by eliminating the need to buttress pit walls for heritage site access and decreasing waste rock dump rehabilitation expenses
Traditional Owner	Access to land	Improving access to land by reducing the necessity for abandonment bunds as more pits can be backfilled to the surface
	Restoration of landscape amenity	Enhancing visual amenity by reducing the number of waste rock dumps remaining at closure and increasing the number of pits backfilled to the surface
	Economic opportunity	Improving economic opportunity through the establishment of a restoration economy employing Traditional Owner contractor companies for pit backfill activities
	Access to clean water	Improving aquifer reinstatement and water quality through regional water schemes
Regulator	Public safety and landform stability	Improving public safety and landform stability by reducing the number of waste rock dumps at closure, thereby removing the slope stability risk while enhancing pit safety and stability through additional backfill, and thus reducing the zone of instability
	No contamination impacts	Preventing contamination by ensuring no potentially acid-forming material is left in waste rock dumps and that it is backfilled below the groundwater level within pits
	Protection of public interests	Increasing the likelihood of addressing a higher number of cultural values, particularly in terms of land access and visual amenity

4 Application in the development of SMART completion criteria

An example of the development of SMART completion criteria using the end state values identified (Figure 2) and applying the mine closure planning ontology (Figure 1) to avoid making category mistakes is presented in Table 4. These SMART completion criteria represent a typical iron ore mine located in the Pilbara, Western Australia. The table includes 'Elements' which are defined as 'the concrete entities in a system' (Table 1) and this example includes pits, a TSF, WRDs and vegetation. End state values are identified for each of the key stakeholders for each of these elements. A shared end state value (i.e. an end state value that satisfies each stakeholder's value) is listed for each element. The SMART completion criteria are then developed based on the shared end state value, since the completion criteria are required to assess whether the shared end state value is being achieved for each of the elements identified in the system. The SMART completion criteria are properties that include indicators and targets. Criteria and indicators remove the ambiguity between the operator and the regulator's interpretation of mine approval conditions that mandate specific reclamation outcomes (Poscente & Charette 2011). Once the targets for each of the properties have been met (i.e. once the SMART completion criteria have been achieved), evidence can be presented to the regulator that the desired end state has been achieved, which will position the mine for site relinquishment.

The shared end state value identified for the pit walls is ‘Safe and unconstrained access’. This addresses the value of ‘public safety’ identified for the regulator, provides reduced ‘Public liability’ for industry and results in ‘Safe and unconstrained access’ for Traditional Owners. The completion criterion for this element is then developed by assessing what is required to ensure safe and unconstrained access around the pit walls, which in this case was identified as ‘Factor of safety provides the same level of public access as natural hillslopes; FoS = >> 2), since Carter et al. (2022) suggest that a FoS = >> 2 is required to allow for unconstrained public access.

The shared end state value identified for TSF run-off is ‘free standing surface water is suitable to support agreed land use’. This value would address the ‘non-polluting’ value for the regulator, ‘compliance’ for the industry and ‘access to clean water’ for the Traditional Owners. The completion criteria developed to assess if this shared end state value is achieved is ‘water qualities are within the agreed site-specific guideline values (SGVs) for all relevant parameters’ since meeting the SGVs will achieve the shared end state value. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZ Guidelines 2019) recommend that SGVs are set to assess water quality and agreed during operations based on monitoring results. The recommended methodology for developing SGVs is detailed by van Dam et al. (2019). Although not presented in Table 4, the SGVs for the relevant water properties set for the mine in question would be included as indicators and targets for the completion criteria set.

The shared end state value identified for WRD side slopes is ‘landform stability’. This would result in meeting the ‘Cost reduction’ value for industry due to a reduced requirement for care and maintenance and would assist in the ‘Restoration of landscape amenity’ for Traditional Owners. The completion criteria developed to assess if landform stability is achieved is ‘erosion rate over rehabilitated slopes is the same as analogous hillslopes; 6t/ha/ annum’. Howard & Loch (2019) found that an erosion rate of 6t/ha/annum is generally suitable for application to WRD side slopes and would be aligned with erosion rates over hillslopes in the Pilbara.

The shared end state value identified for vegetation is ‘self-sustaining natural vegetation’. This would address the ‘Environmental protection’ value for the regulator, minimise care and maintenance costs for industry (i.e. address the ‘cost reduction’ value) and provide ‘availability of traditional resources’ for Traditional Owners since the natural vegetation would inherently include traditional resources. Traditional resources in this context are environmental resources used by Traditional Owners for cultural and spiritual purposes. The completion criteria set to assess if this shared end state value is met is ‘Density of keystone cultural species per ha is equivalent to relevant reference site’. Smith (2009) defines keystone cultural species as ‘species that assume iconic or totemic standing, and feature prominently in the language, ceremonies, and narratives and underpin the social fabric because they play fundamental roles in diet, as materials, or in medicine’. Although not presented in Table 4, the quantitative density of keystone cultural species required per hectare (as inferred from a relevant reference sites and agreed with Traditional Owners) for the mine in question would be included as a target for the completion criteria set.

The completion criteria presented in Table 4 are generally considered SMART since they are specific and measurable (i.e. they include indicators and targets to measure the property required). Whether they are achievable and realistic is dependent on the site-specific context and operational monitoring results. Where possible, the indicators and targets set for each of the properties should be compared against operational monitoring results to assess if these are achievable and realistic. The are no time restrictions set in meeting these criteria, however, it is possible to predict how long it will take to meet the criteria through predictive modelling in the case of water quality, or through scheduling in cases where this is related to engineered construction (i.e. pit wall slopes), and the predicted time required to meet the criteria should be included where available.

Table 4 Example of the development of SMART completion criteria using end state values

Element	Regulator values	Industry values	Traditional Owner values	Shared end state values	Completion criterion	Reference for indicator/ target
Pits (pit wall)	Public safety	Public liability	Safe and unconstrained access	Safe and unconstrained access	Factor of safety (FoS) provides the same level of public access as natural hillslopes FoS = >> 2	Carter et al. (2022)
TSF (run-off)	Non-polluting	Compliance	Access to clean water	Free standing surface water is suitable to support agreed land use	Water qualities are within the agreed site-specific guideline values (SGVs) for all relevant parameters *SGVs targets for relevant parameters would be stated here for use as targets*	ANZ Guidelines (2019) van Dam et al. (2019)
WRDs (side slopes)	Landform stability	Cost reduction	Restoration of landscape amenity	Landform stability	Erosion rate over rehabilitated slopes is the same as analogous hillslopes *6 t/ha/annum*	Howard & Loch (2019)
Vegetation	Environmental protection	Minimising rehabilitation maintenance (i.e. promoting passive care)	Availability of traditional resources	Self-sustaining natural vegetation	Density of keystone cultural species/ha is equivalent to relevant reference site *Reference site keystone cultural species/ha would be stated here for use as target*	Smith (2009)

5 Conclusion

Navigating divergent stakeholder expectations in the development of SMART completion criteria can be a challenging process. Establishing clear and agreed-up completion criteria is essential for the successful transition of mined land to its designated post-mining use and ultimate site relinquishment. Despite the importance of completion criteria, there remains a significant need to improve the setting of targets and the development of measurable completion criteria that are accepted by all stakeholders involved (Kragt & Manero 2021). These challenges can, however, be mitigated through a collaborative effort that is based on a solid foundational framework, or ontology, and supported by a robust understanding and description of the desired end state and the closure objectives required to achieve these. Once these foundational aspects are understood and applied, the appropriate completion criteria development framework of choice can be used to guide the development of SMART completion criteria.

Mine closure planners should be aware of category mistakes and should develop completion criteria from a common mine closure planning ontology to avoid category mistakes, improve consistency and reduce confusion in setting SMART completion criteria. The desired end state should be derived by identifying the end state values of each of the key stakeholders, generally including industry, regulators and Traditional Owners, which can only be achieved through appropriate engagement. Native title rights must be considered when developing SMART completion criteria and the consideration of Traditional Owner end state values should inherently incorporate these rights. Once the desired end state values for each of the key stakeholders are identified, shared end state values should be determined and used as the basis for setting the desired end state or closure vision. Closure objectives should then be developed to describe the desired end state values for each of the elements identified within the closure system. The SMART completion criteria are then developed as a set of properties including indicators and targets to assess whether the desired end state has been achieved.

This collaborative approach has the potential to accelerate the use of co-design in mine closure planning. Both processes are concerned with ensuring the outcomes of mine closure meet the needs of all stakeholders and that the post-mining land use is acceptable to stakeholders. Exploring how the development of SMART completion criteria that reference the desired end state values of key stakeholders can initiate co-design is a topic worth further consideration.

To further enhance the development of SMART completion criteria for mine closure, a regional approach to mine closure should be adopted. This strategy not only reduces mine closure risks through advanced mitigation strategies but also yields mutual benefits for mining regions by establishing meaningful SMART criteria, thereby increasing the likelihood of fulfilling these criteria and further promoting successful site relinquishment.

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