ICMM Mining with Principles

Integrated Mine Closure

Good Practice Guide, 2nd Edition

Updated February 2025

Contents

Abbreviations

AR5	Fifth Assessment Report [of the IPCC]
ARD/ML	Acid Rock Drainage and Metal Leaching
CCM	Critical Control Management
CDA	Canadian Dam Association
CEP	Closure Execution Plan
EPCM	Engineering, Procurement And Construction Management
ESIA	Environmental and Social Impact Assessment
GAAP	Generally Accepted Accounting Principles
GARD	Global Acid Rock Drainage [Guide]
GIS	Geographic Information System
GISTM	Global Industry Standard on Tailings Management
ICMM	International Council on Mining And Metals
ICPS	Integrated Closure Planning System

IFRS	International Financial Reporting Standards
IPCC	Intergovernmental Panel on Climate Change
LoA	Life of Asset [Includes Post-Closure Period]
LoM	Life of Mine [To End Of Productive Mine Life]
NGO	Non-Governmental Organisation
NPV	Net Present Value
OMS	Operation, Maintenance and Surveillance
PTNMR	PT Newmont Minahasa Raya
QA/QC	Quality Assurance/Quality Control
RACI	Responsible, Accountable, Consulted, Informed
SMART	Specific, Measurable, Achievable, Relevant, Timely
TEDWG	Thompson Economic Diversification Working Group
UHMD	Upper Hunter Mining Dialogue

Foreword

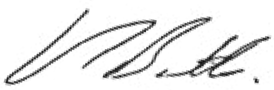
Mineral and metal resources are finite, meaning that mining is a temporary land use. Closure is an important phase of every mining or metals processing operation and presents an opportunity to strengthen environmental, social and economic resilience far beyond the mine's life cycle. Responsible mine closure involves planning and designing for closure in consultation with relevant authorities and stakeholders to achieve sustainable outcomes that are beneficial to the mining company and its employees, the environment and host communities and countries. This should be done at an early stage of mine planning and development and dynamically throughout the life of the mine.

ICMM members commit to enabling agreed closure and post-closure commitments to be realised through planning, designing for and implementing closure in consultation with relevant authorities, internal and external stakeholders, and to make financial provision, in order to address the environmental and social aspects of closure.

ICMM's Integrated mine closure: good practice guide provides mining companies with the guidance needed to effectively integrate closure across the mining life cycle. This in turn creates the opportunity for companies to be proactive in identifying and addressing risks early before they become material with the potential to compromise eventual mine closure, as well as to building stakeholder confidence. The guide is intended to support the goal of delivering a positive legacy while balancing environmental protection and social well-being with financial performance.

This guide is applicable to new mines, existing mines and legacy sites, and is intended for use across the spectrum of mining companies, from major multinationals to single asset junior mining companies. The guide is not exhaustive but does establish the practices and expectations for closure applicable at a broad variety of sites and can be used as guidance on the standard of practice for sites in the absence of formal regulatory/government requirements. It has been designed to be largely compatible with different regulatory regimes and corporate guidelines.

The closure process has historically relied on the mining company's expertise to conceptualise and deliver results. In modern practice, communities and governments also play a key role in creating successful closure outcomes. As such, integrated closure planning and implementation needs to capture and balance the views, concerns, aspirations, efforts, knowledge and capacity of relevant internal and external stakeholders. The goal is to achieve sustainable outcomes that are beneficial to the mining company and its employees, the environment and host communities.



Rohitesh Dhawan
President and CEO, ICMM

Executive Summary

The Integrated mine closure: good practice guide provides ICMM members and other responsible mining companies with guidance intended to promote a disciplined approach to integrated closure planning and to increase the uniformity of good practices across the sector.

This guide presents an updated version of ICMM's 2008 *Planning for integrated mine closure: toolkit*. Like the earlier version, guidance is provided on critical aspects of mine closure focused on an iterative process, from the earliest stages of knowledge gathering, engagement and planning. The updated guide provides emphasis on the importance of social transitioning, progressive closure and strategies for relinquishment and closure governance. The guide also includes tools at the back of this document to help support planning for closure.

Integrated mine closure is a dynamic and iterative process that takes into account environmental, social and economic considerations at an early stage of mine development.

Fundamental to this process is the need to consider closure as an integral part of the mine operations' core business. The structure of this guide reflects this process, providing good practice guidance in delivering key elements of mine closure planning and implementation, including:

— **Integration into life of mine planning** and early definition of the **closure vision, principles and objectives** supported by both early **engagement for closure plan development** with stakeholders and development of a **knowledge base** where data will be collected and updated throughout the mining life cycle. The definition of the closure vision, principles and objectives is underpinned by considerations of potential **post-closure land use** of the former mine site, and a formal **identification and assessment of risks and opportunities** throughout iterations of the closure plan.

— Implementation of various **closure activities** to implement closure, both during the mine life as progressive closure and as part of final closure. These closure activities should be tied to meeting specific closure objectives that have been defined and agreed. **Monitoring** will be undertaken to document and evaluate the effectiveness of the closure activities at meeting agreed closure objectives and the **success criteria**. The development of well-defined success criteria, with input and agreement with appropriate stakeholders, are key to completing closure works.

— Implementation of **progressive closure**, which involves the implementation of closure activities during the operating life of a mine providing opportunities to test and demonstrate the effectiveness of closure activities, validate success criteria and build trust with communities and the regulators. It provides opportunities to generate learnings that can be incorporated into closure planning throughout the mining life cycle.

— Planning and preparation for **social transition** to help reduce the negative impacts of social change for the workforce and communities connected to the mine site and improve the legacy of benefits from mining activities.

— Understanding of **closure costs** for the purposes of planning, comparing alternatives, understanding financial liabilities and complying with reporting and financial assurance obligations.

— Developing and updating a **closure execution plan** while ensuring adequate **closure governance** structures are in place to ensure closure planning is integrated into the life of mine planning. The closure execution plan identifies actions and resources required during the mine life to support planning and implementation of closure, while appropriate governance ensures effective allocation of resources to closure across a range of disciplines.

— Periodic evaluation of appropriate 'what-if' scenarios during the mine life to help minimise the disruption caused by such unplanned events. Unplanned changes in circumstances can result in **temporary** or **sudden closure** of mines.

— **Relinquishment** of closed sites to a third party, which may not always be possible, but it should be a desirable endpoint of the life of asset (the entire mining life cycle, including post-closure). Detailed planning and robust execution of closure throughout the mining life cycle can help increase the probability of attaining successful relinquishment.

This guide has been structured as per the above process described. However, in practice there are many feedback loops that interconnect each element – hence the need for an iterative process. Furthermore, the guide provides good practices, case studies and a range of tools that can be utilised in formulating well-considered decisions when planning and executing closure.

Summary of tools

Tool 1	The domain model
Tool 2	Monitoring, measurement and inspections
Tool 3	Objective setting
Tool 4	Screening alternatives for repurposing
Tool 5	Key messages for social transition
Tool 6	Social transition activities checklist
Tool 7	Climate change and mine closure concerns
Tool 8	Risk/opportunity assessment and management
Tool 9	Considerations in developing closure activities for transversal issues
Tool 10	Considerations in developing closure activities for domain-specific issues
Tool 11	Social investment for closure
Tool 12	Closure plan documentation

Introduction 01

The International Council on Mining and Metals (ICMM) has developed *Integrated mine closure: good practice guide* to support the needs of company members and other responsible mining companies as they plan for closure. This document is intended to promote a disciplined approach to integrated closure planning and to increase the uniformity of good practices across the sector. The concepts apply equally to both large and small mining companies.

The document is not intended to be prescriptive. It provides guidelines, good practices, case studies and a range of tools that can be utilised in formulating well-considered decisions when planning and executing closure. It uses a risk and opportunity-based process to guide the practitioner through the iterative process of planning for final and progressive closure in a considered manner, as well as tactics for considering sudden or temporary closure.

A balanced closure approach fully incorporated into mine planning activities will lead to better outcomes across a range of considerations, including health, safety, social, environmental, legal, governance and human resources.

Effective closure planning results in:

- consistent and transparent engagement with stakeholders.
- community participation in planning and implementing actions that underpin successful closure.
- stakeholder support of closure decisions.
- better management of closure throughout the mining life cycle.
- more accurate closure cost estimates.
- early identification of risks and mitigation strategies.
- progressive reduction of liabilities.
- working towards an agreed-upon vision for the post-closure period.
- a better social transition for affected stakeholders as the mine moves from operations to closure
- opportunities for lasting benefits being recognised and planned for adequately.

As shown in Figure 1, closure needs to be considered throughout the life of asset (LoA). Designing for mine closure must be integrated into planning from the earliest stages of exploration and mine development. Early consideration of mine closure will make it easier and more cost-effective to achieve final closure objectives and can improve the opportunities for relinquishment.

Some typical examples of designing for closure throughout the LoA are:

— making areas available for progressive closure in order to limit closure impacts and liabilities at final closure.

— sequencing the stripping and storage of topsoil during development to facilitate direct placement in areas to be reclaimed – this reduces haul distances and preserves topsoil quality.

— strategic placement of potentially reactive materials to facilitate their isolation and avoid groundwater contamination.

— designing waste disposal facilities with long-term physical stability and maximised in-pit dumping, minimising closure earthworks at closure.

As the mine proceeds through construction, operation, final closure and the post-closure period, various domains or portions of the mine may be closed while operations continue (a process known as progressive closure), with final closure taking place at the end of the life of mine (LoM). As shown in Figure 1, implementation of closure activities, whether final or progressive, will be preceded by the development of more detailed plans and designs. This typically includes a progression through conceptual, pre-feasibility and detailed designs (although the exact terminology for these stages may vary between mining companies).

While Figure 1 shows a linear process for the **implementation** of closure, **planning** for closure is an iterative process, with the closure plan refined and updated throughout the LoA. Closure planning is cyclic as information relevant to closure is updated and gathered. This information may come through many different sources, such as ongoing engagement with communities and other stakeholders as ideas and expectations for closure evolve, studies are developed to address gaps in the knowledge base, changes in technology, or learnings gained through the implementation of progressive closure. The earliest progressive closure activities will typically provide learnings that can be incorporated into later progressive closure activities and final closure.

Figure 1: Integrated Mine Closure Framework

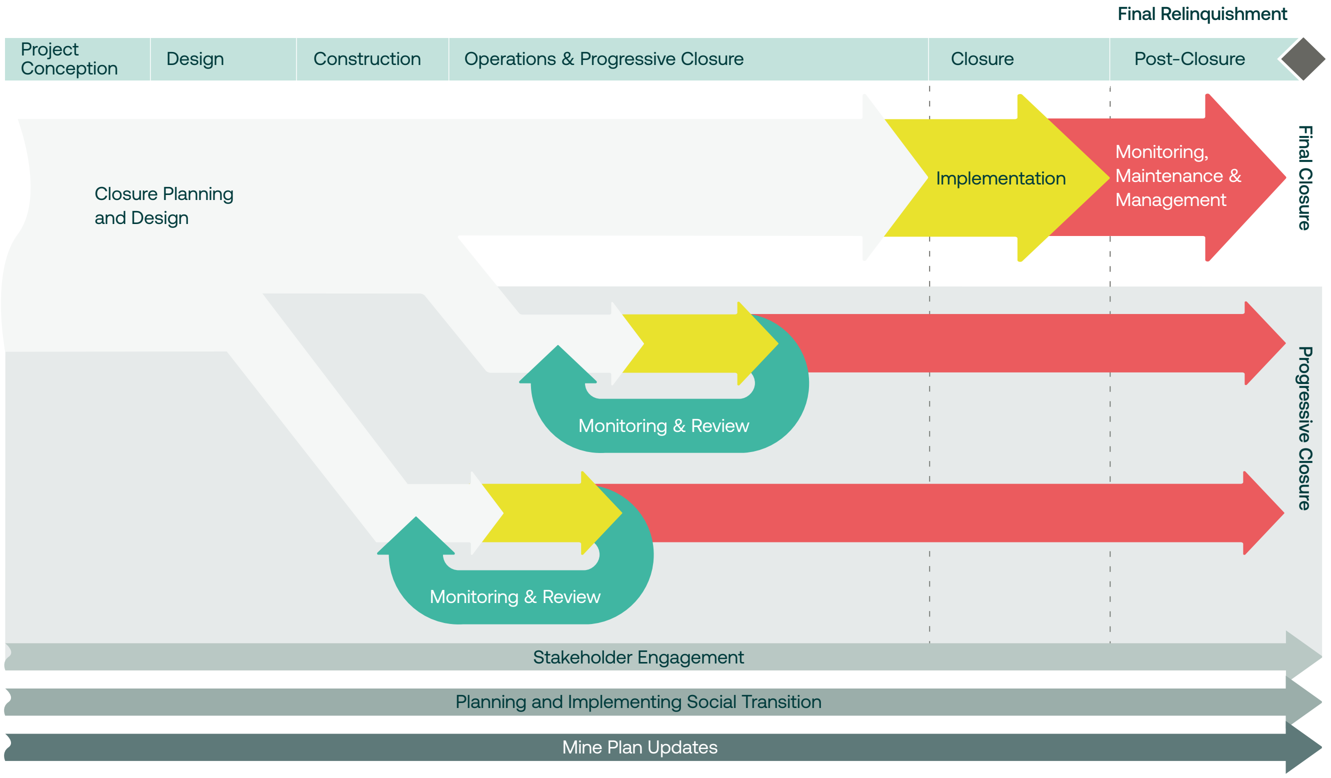


Figure 2: Elements of Closure Planning

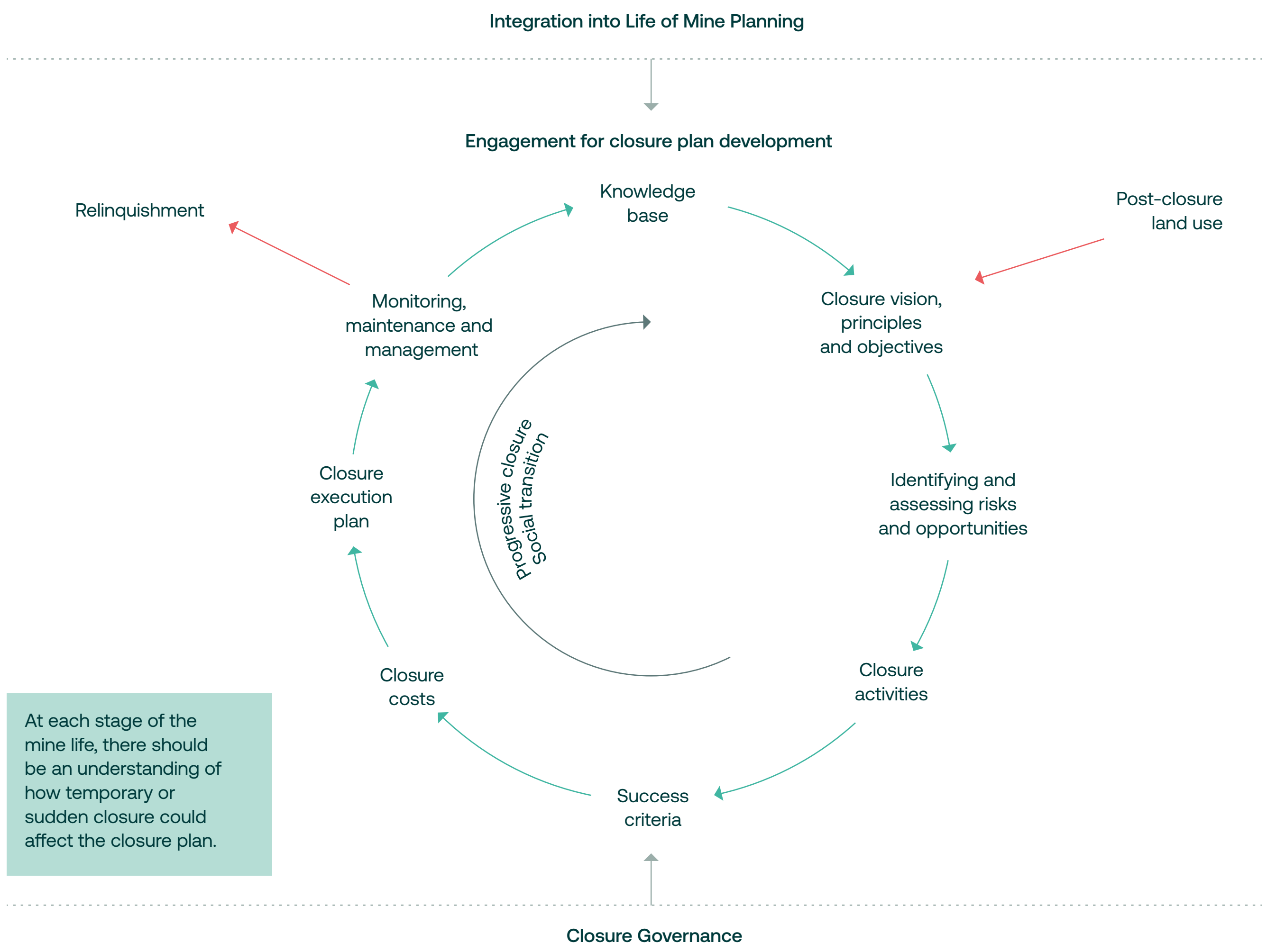


Figure 2 illustrates key elements of mine closure and a pathway through them aligned with the organisation in this guide, although the steps through the planning cycle will not necessarily be sequential. In practice, there are many feedback loops that interconnect each element – hence the need for an iterative process.

Each of these elements for the planning process are summarised below.

1. Integration into life of mine planning: Closure should be integrated into the mine business plan, including the short, medium and LoM planning processes, throughout the mine life. When closure is fully embedded in LoM planning, there are better results as expectations, risks and opportunities can be proactively managed and achieved for the mining company and stakeholders.

2. Knowledge base: The knowledge base is the repository for information that will be developed throughout the LoA, with regular updates as data is collected and reviewed. This is the information that will inform site-specific closure planning, such as the environmental and socioeconomic setting, environmental baseline data, operational data (such as volumes and types of waste currently and planned to be deposited, waste characterisation), commitments and compliance requirements.

3. Closure vision, principles and objectives: These will be defined early in the closure planning process and refined throughout the LoA with input from stakeholders and the knowledge base. The closure vision is an aspirational description of what will be achieved with mine closure, compatible with regulatory requirements. The vision will typically incorporate an overview of the post-closure land use and will evolve as more information becomes available. Closure principles are the common precepts that guide the basis of a closure plan, such as promoting physical and chemical stability, meeting regulatory obligations and facilitating social transition. The closure objectives indicate in concrete terms what is to be achieved through implementation of the closure activities.

4. Post-closure land use: Where the use of the land after mining can be defined, this greatly aids closure planning. A defined post-closure land use, or range of possible post-closure land uses and required land capabilities, will inform all aspects of the closure plan, particularly the definition of both the closure vision and objectives.

5. Engagement for closure plan development: Engagement with stakeholders will take place throughout the closure planning process, with insight from that engagement used to shape key elements of the closure plan.

6. Identifying and assessing risks and opportunities: A wide range of risks and opportunities are associated with closure, covering physical, social, economic and ecological considerations. Formal identification and evaluation of risks and opportunities helps to set priorities and shape many aspects of the closure plan, including the selection of closure activities.

7. Closure activities: Specific closure actions or works are executed in the implementation of the closure plan, both at final closure and progressively through the LoA. Examples include installation of a tailings cover, reshaping waste dumps, commissioning of a water treatment plant and removal of contaminated soil.

8. Success criteria: These are developed as quantitative indicators of successful closure activities. Meeting success criteria can mark the end of the post-closure period for a mine or part of a mine. This may be associated with the return of the associated financial assurance amount to the mining company, an opportunity for relinquishment of the land to a third party, or both.

9. Progressive closure: Progressive closure is the implementation of closure activities during the operating LoM. There are many benefits to implementing progressive closure, including the learnings that can be integrated into the knowledge base.

10. Social transition: This encompasses the efforts that are associated with transitioning of a community, including its workforce, towards closure of an operation. These efforts take place throughout the LoM and into closure.

11. Closure costs: A key part of the closure planning process is estimating the cost of all aspects of closure, and updating those estimates as plans evolve and more information becomes available.

12. Closure execution plan (CEP): A CEP will be developed and regularly updated through the closure planning process. While the closure plan describes the actions that will be carried out as part of implementing site closure, a CEP identifies specific actions to be carried out during the mine life in support of closure planning and implementation of closure activities.

13. Monitoring, maintenance and management: Following the completion of closure activities, monitoring should be carried out to document and evaluate the effectiveness of the closure activities at meeting agreed closure objectives and to demonstrate that success criteria are being met, or on a pathway to be met. Monitoring of sites against success criteria may lead to the identification of maintenance needs. Rehabilitated areas may also need to be managed as part of the broader ecosystem.

14. Relinquishment: Relinquishment is not always the endpoint for the LoA, but it is a stated objective for many mine sites. Attaining relinquishment requires careful planning and engagement with an appropriate regulatory regime. Where relinquishment is planned, ongoing engagement with stakeholders will be required leading up to the eventual relinquishment, with attention to developing agreed-upon success criteria.

15. Temporary or sudden closure: Various factors can result in the temporary or unplanned closure of an operating mine. At each stage of the mine life, there should be an understanding of how temporary or sudden closure could affect the closure plan. This understanding will need to be updated regularly over the mine life.

16. Closure governance: An overarching approach to closure governance is needed to ensure the effective allocation of resources to closure planning from many disciplines across the mining company, including both site resources and, where available, corporate support. Effective closure governance will affect every aspect of closure planning at an operation.

This guide provides guidance on each of the above topics. The guide also includes supplementary information in the form of a series of tools to aid the practitioner in developing closure plans and carrying out activities in support of closure. The relevant tools are listed throughout the document.

The practice of mine closure continues to evolve globally. Case studies drawn from the experiences of both ICMM member companies and other mines are presented throughout the document to illustrate recent, practical experience with mine closure at sites around the world. Practices such as repurposing mines at closure for beneficial uses are now becoming commonplace, and many mining companies are seeking to integrate the social component of closure planning into how they do business, with ongoing consultation throughout the planning and implementation of operations and closure.

Good practice: Closure planning should be incorporated into the earliest stages of mine planning, including exploration, so closure risks and opportunities are captured from the start and proactively managed in order that closure is fully considered in the mine design and business plan.

Integration into Life of Mine Planning

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Designing for closure means integrating closure activities into the mine business plan, including the short, medium and LoM planning processes, throughout the mine life taking into account environmental, social and economic considerations. Integrated mine closure should integrate stakeholder involvement and community consultation throughout the mining life cycle.

The benefits of this integration can include the following:

— closure decisions will be better supported by stakeholders.

— assets are designed and operated with closure as a key input variable.

— better understanding of closure risks and knowledge gaps throughout the business.

— value generation by realising opportunities through the operational phase.

— liabilities progressively reduced or prevented, where practicable.

— costs reduced through operational synergies.

— increased efficiency through reduction in double handling of materials.

— minimise the risk of regulatory non-compliance.

— adequate financial provisioning for closure is allocated.

— reduce risk of an extended period of care and maintenance at the end of the mine life due to inadequate closure planning.

— better understanding of closure liabilities to inform change of ownership decisions.

— improve accuracy of closure cost estimates.

— recognise and adequately plan for post-mine land use opportunities.

As with closure planning itself, integrating closure into the LoM plan is an iterative process that incorporates developing information and experience over the mining life cycle. The earlier this approach is followed in the life of a mine, the greater the opportunity for proactive planning. This provides a consistent approach over the life cycle of projects for reporting and management of long-term liabilities in ensuring a positive social and environmental legacy is left behind post-closure. See BHP's and Anglo American's case study examples on integration of closure into LoM planning.

Case Study

Delivering closure landforms through mine planning in Western Australia (BHP)

At BHP's Western Australia Iron Ore, a closure and rehabilitation governance strategy specifically supported by guiding principles, coupled with waste and landform design knowledge, has enabled LoM planning to drive optimisations that target both operational production and closure outcomes.

Western Australia Iron Ore experienced significant benefits from this approach to planning waste disposal. A recent project involved taking pre-feasibility (conceptual) level mine layouts and schedules to a feasibility (detailed) level resulting (prior to mine execution) in the following benefits:

- more than 50 per cent reduction in land disturbance by optimising in-pit dumping and haul road designs.
- more than 60 per cent increase in void backfilling, including over a 30 per cent increase in progressive backfill of pits where that backfill was needed to manage potential post-closure impacts.
- reduced number of waste disposal areas that would require rehabilitation, thus reducing closure costs.
- pit, waste disposal area and haul road development sequences for the whole mine life developed in a manner that will reduce rework, optimise fleet utilisation and reduce capital expenditure.
- increased confidence in the ability to execute progressive rehabilitation.
- increased ability to manage closure risk through either avoidance or early mitigation of risk issues – this reduces post-closure residual risks.
- improved communication of closure and rehabilitation risks and proposed management measures to stakeholders.

Kolomela Iron Ore open pit, South Africa

Case Study

Integrated closure planning with other mine-planning processes (Anglo American)
Anglo American commenced the development of an integrated closure planning system (ICPS) with the aim to provide a consistent approach over the life cycle of projects for the reporting and management of long-term liabilities, to achieve their goal of ensuring that they leave a positive and sustainable legacy post-closure.

To achieve this objective, focus on people, process and technology was required. The elements of the ICPS are planning (eg LoM, closure, short/medium-term mine, rehabilitation), financials (eg premature and LoM closure liability, operational expenditure, guarantees), systems (eg closure toolboxes, geographic information systems, environmental management systems) and requirements (eg internal/external standards, policy, regulation).

The system involved identifying the current state of processes, the target state of a fully integrated process, developing a maturity scorecard and identifying potential technology solutions that may assist in realising value at the operational level.

In defining the current condition across the operations, it became evident that roles and responsibilities were not clear across the organisation; both the LoA and shorter term mine planning processes had no clear platform or process to facilitate closure planning interactions. This finding reinforced the importance and emphasised the critical nature of the ‘people, process and technology’ elements.

Through application of a balanced scorecard, and Anglo American’s internal assessment of its operations across the globe, potential pilot mine sites were identified with low, moderate and high levels of ICPS maturity, with associated high closure risk or opportunities. Project implementation plans were developed to increase the ICPS maturity at the pilot sites to the required level that will maximise value realisation or minimise value destruction from a mine closure perspective.

Key questions to ask about integration into LoM planning

Has a multidisciplinary team provided input to the short, medium and LoM planning processes? Is there integration between the closure, mine engineering/planning, environment and community teams in planning for closure?
Has the closure vision been clearly communicated to the LoM planners? Do LoM planners understand the potential added value of designing for closure?
Are the roles and responsibilities of teams clearly defined in achieving the overall closure vision?
Is there a platform/system in place to ensure integration between teams and incorporation of closure into the mine business plan?

Knowledge Base

Tool 1	The domain model
Tool 2	Monitoring, measurement and inspections

The knowledge base is site-specific and domain-specific information used in the closure plan.

The knowledge base typically covers four areas:

— physical.

— environmental.

— social/socioeconomic.

— regulatory.

The information can also be organised in domains, which consider the mine site as an aggregation of specific areas with related characteristics. Tool 1: The domain model can be used to help organise information for domains. The information gathered for each area or domain should include its status, historical information, technical information (such as dimensions, concentrations, environmental and social baseline conditions and trends, and chemical and hydrogeological characterisations) and local and traditional knowledge, where available and appropriate. Tool 2: Monitoring, measurement and inspections provides information relevant for collecting information to be added into the knowledge base. Document control and quality assurance/quality control (QA/QC) are important to verify that the information within the knowledge base is current, readily accessible and accurate.

The collection, updating, use and review of the knowledge base in each of these areas is an ongoing and iterative process over the mine life, used to inform the closure planning process. Gaps and uncertainties will be identified over the mining life cycle, with studies, research and trials undertaken as needed to close knowledge gaps. Significant development of the knowledge base typically takes place during the environmental assessment stage, through baseline studies, and future-looking evaluations of potential impacts and mitigation measures. The construction of the mine will alter many aspects of the pre-mining characteristics. The plans to address gaps and uncertainties over the life of the mine should be incorporated into the CEP and used to inform closure planning and implementation.

Throughout the mine life, monitoring will be conducted in each of the areas covered by the knowledge base. The data collected will be reviewed, assessed and incorporated into the knowledge base. For example, monitoring and inspection of revegetation during progressive closure could provide data on both vegetation growth rates and maintenance issues encountered while addressing erosion. Learnings can be taken from review of this data and incorporated into the knowledge base for use in the refinement of future closure activities.

This knowledge will inform all aspects of the closure plan, from setting the vision and objectives, through to designing engagement programmes, evaluating risks, selecting closure activities and defining success criteria. More specifically, the information gathered in the knowledge base allows:

- complexity of the environmental and social setting to be better understood.
- identification and assessment of closure risks and opportunities.
- identification of data gaps and development of activities to close them.
- identification and assessment of potential post-closure land uses.
- support for development of success criteria.
- identification of trends, in both environmental and socioeconomic data.
- understanding of cumulative impacts and changes that may result from commissioning or decommissioning of other industries that have influence over the mine's project area.
- identification and assessment of possible closure-related impacts and operational management or mitigation.
- mitigation of some of the risk that comes from turnover of closure practitioners.

Risk assessment and the knowledge base

No matter what kind of risk assessment is being carried out, the usefulness of the assessment will depend on the quality of the information used. Gaps in the knowledge base may affect confidence in a risk assessment.

Good practice: A knowledge base gap analysis should be undertaken at regular intervals throughout the mine life (at least once per closure plan update) to identify further studies, research or trials that may be required, as informed by the risk assessment. These are then incorporated into the CEP according to their time frame and significance.

The risk assessment process will highlight gaps in the knowledge base and allow prioritisation of studies and activities to fill these gaps (see section 7 on identifying and assessing risks and opportunities). If combined with a closure cost evaluation, the risk assessment can focus attention not only on understanding the main risks, but also on identifying and quantifying risks driving the overall closure cost.

As an example, knowledge gaps in the capping design of a tailings storage facility are likely to have a significant impact on the level of confidence in final facility closure costing, which can present a business risk. In this case, enhancing the knowledge base related to tailings cover could become a priority.

Operating with and without a regulatory framework

Countries vary considerably in terms of mine closure regulatory and legislative requirements. In some countries, detailed mine closure regulations are well established, while in others there is limited (or no) applicable legislation. In countries with new or changing regulatory requirements, there can be a lack of regulatory experience. In countries where limited or no mine closure regulations exist, mining companies may need to manage uncertainty, and the knowledge base should consider regional and national development plans.

Good practice: In the absence of country-specific mine closure regulations, mining companies should consider applying requirements for closure that are consistent with good practices in more mature regulatory environments. Companies should engage regulators early in the process to improve alignment on expectations, understand regulator objectives and communicate mine closure processes and objectives to reduce uncertainty.

In the absence of a clear local regulatory framework, there are other sources of commitments that should be considered in the knowledge base. These include international commitments, treaties, investment agreement requirements, corporate commitments, disclosure requirements and reporting related to standards such as National Instrument 43-101 or the JORC Code, and the International Financial Reporting Standards (IFRS) or in the USA the Generally Accepted Accounting Principles (GAAP).

Key questions to ask about the knowledge base

Have proper baseline and pre-mine data been collected? Is the data sufficient for evaluating closure needs? Does the data include proper documented QA/QC information?
Is additional information for the knowledge base required?
Are the tools and/or methodologies in place to obtain additional information?
Are volumes and characteristics of waste being characterised as they are being planned, generated and paced with statistically significant sampling programmes?
Has spatial data been generated showing the mining operation and the associated communities, water resources, infrastructure and ecologically sensitive or protected areas? Does this include clear definition of the surface water and groundwater watersheds?
Have relevant regulations (mining and non-mining) been reviewed and understood, including proposed or foreseeable changes? Relevant non-mining regulations to consider include labour laws (as applicable to workforce retrenchment), water use regulations and environmental regulations.
Are relevant corporate standards incorporated?
Have commitments and legal obligations of the company to relevant stakeholders been captured, as well as their expectations?
Has stakeholder consultation been conducted, with emphasis on identification of the closure risks and opportunities related to employees and the community?
Have stakeholders been consulted on post-closure land use? Is there an existing land use or tenure plan that identifies expected post-closure land uses within the broader area of operations?
Are appropriate data management protocols in place to ensure that data from activities such as ongoing monitoring and field trials are incorporated into the knowledge base?
Have commitments made through membership in organisations such as ICMM been documented?

Closure Vision, Principles and Objectives

Tool 3	Objective setting

The aims of the closure plan are set out through its underlying vision, principles and objectives. Each of these are defined and discussed in further detail below. Site-specific closure objectives are developed taking into consideration the overall vision for the site and closure principles that may be applicable to a broad range of sites. While different companies may use different terminology for these concepts, the underlying approach is usually similar.

Closure vision

The closure vision provides a high-level aspirational description of what an operation or company and stakeholders want to achieve through implementation of the closure plan. This includes how the company will be remembered, as the way a company exits a mine site can impact positively or negatively on its reputation. Reputational impacts can in turn affect the company's social licence to develop or operate mines. The closure vision is a guiding statement for the development of the closure plan. The closure vision typically includes elements of post-closure land use and must align with regulatory obligations. It should be endorsed by senior site or company leadership.

Good practice: Begin with defining a closure vision that articulates what a company wants to achieve post-closure and the legacy it will leave behind. Involve stakeholders early in the development so that it can become a shared vision. This vision will serve as an overarching guide for the decisions and their implications throughout the mining life cycle.

Closure principles

Closure principles are general in nature and are typically applicable to a wide range of sites and conditions. For example, the promotion of physical and chemical stability are universally accepted closure principles. While the terminology may be different, many mining companies have their closure principles codified in their internal closure policies. The following are standard closure principles widely used and considered good practice:

— **Safety:** to promote physical safety of the closed mine site over time by the provision of closure activities to make safe (to human and animal) any void or pit left after mining to prevent falls from height.

- **Physical stability:** to promote physical stability or the physical sustainability of the closed mine site over time, creating a physically stable landscape that limits long-term erosion potential and environmental degradation in the long term such that there is little or no safety threat or risk to personnel or the environment due to excessive movement of permanent landforms. The physical stability should be compatible with access and the intended post-mining land use. There may be limitations to the practically achievable physical stability of some landforms; however, the closure design should be developed to manage safety risk over prolonged periods.
- **Chemical stability:** to prevent adverse effects on the local environmental quality by chemical contamination arising from the site. Acid rock drainage and metal leaching (ARD/ML) are common chemical stability issues, but there are a wide range of others that can arise from site-specific conditions. The chemical stability should be compatible with the intended post-mining land use.
- **Socioeconomic transition:** to promote, to the extent practical, a smooth transition from the socioeconomic conditions that existed during mining activities to the state that will be present after mining. Where practicable, the net socioeconomic impact on the affected region should be beneficial.
- **Ecological stability:** to ensure the post-closure ecosystem at the closed site is either stable, and remains in a sustainable state, or on a desired trajectory, compatible with the planned post-closure land use. This may include goals for biodiversity and for a self-sustaining ecosystem that will be viable in the long term without ongoing mining company support, and compatible with the proposed land use.
- **Risk limitation:** to control risk to an acceptable level, in a number of distinct areas (such as safety, environmental, financial, legal compliance, social, reputation). Most mining companies will look at closure through a risk assessment framework, in which controlling risk is commonly an implicit or explicit principle.
- **Cost-effectiveness:** to execute the closure activities cost-effectively, and efficiently use the technical, financial and human resources required to implement closure.
- **Long-term care:** to design the closure plan to minimise or eliminate the need for long-term post-closure care and maintenance. This principle is closely tied with chemical, ecological and physical stability and may be tied with achieving relinquishment of the closed site where that is an objective.

Closure objectives

While the closure vision provides overarching direction for closure, and the principles provide a general framework, the closure objectives provide concrete, site-specific and typically measurable statements of what closure activities or measures aim to achieve. Individual objectives may be specific to mine domains such as pits, infrastructure and waste disposal facilities, or to aspects of closure. For instance, a site-specific objective could be that water quality in a flooded pit is safe for wildlife to drink.

The selection of closure objectives should be informed by consideration of risks and opportunities. Early identification of risks associated with closure allows possible impacts to be avoided or mitigated in a timely manner, which ultimately reduces the closure liabilities and improves post-closure benefits.

Development and refinement of vision, principles and objectives

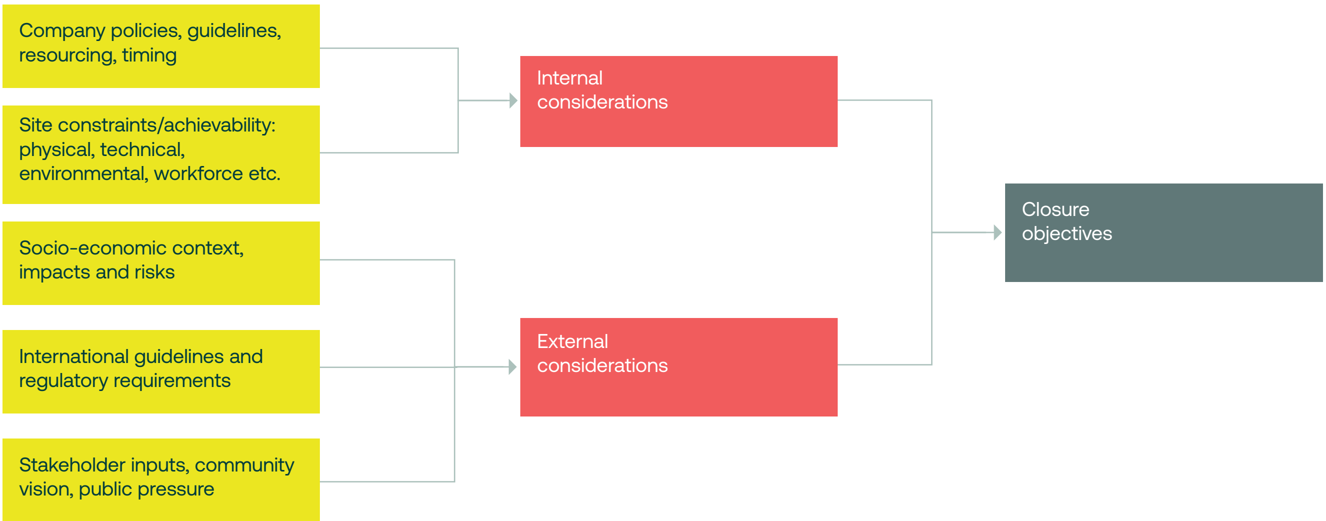
Establishing and then refining the closure vision and objectives over the mine's life cycle should be an integrated, multidisciplined and multi-stakeholder process. Engaging and aligning internal and external stakeholders will lead to more successful outcomes. As the closure principles are not site specific, they are not expected to change over time, although new principles may be added as mine closure practices evolve. In contrast, the development of the closure vision and objectives is typically an iterative process, and both may evolve over the LoA.

Both the closure vision and closure objectives should be informed by the knowledge base, particularly the mine's zone of influence, socioeconomic and environmental context, stakeholder relationships, country-specific requirements and other external drivers (such as alignment with the International Finance Corporation's Performance Standards, the Sustainable Development Goals or other requirements such as ICMM's performance expectations). Full consideration of these factors should lead to a closure vision and closure objectives that are aligned with the characteristics of the corporation and the closing mine and appropriate to its socioeconomic setting. Figure 3 illustrates the types of inputs that are typically considered in the development of closure objectives. Tool 3: Objective setting can help with developing the closure objectives.

The development of the closure vision and objectives is usually greatly shaped by post-closure land use considerations. As an illustration, the example objective mentioned earlier (ie that water quality in a flooded pit is safe for wildlife to drink) would likely be developed considering a post-closure land use where wildlife is expected to have access to the pit.

Good practice: Consider post-closure land use in the development of both the closure vision and site-specific closure objectives. Involve internal and external stakeholders early in the consideration of possible post-closure land uses.

Figure 3: Inputs to Closure Objectives



Key questions to ask about the closure vision and objectives

Has a long-term, overarching and site-specific closure vision been developed?
Does the closure vision consider environmental, community, workforce and financial concepts?
Did the development of the closure vision account for legal and health and safety constraints on land use?
Does the closure vision address the desired post-closure land use?
Has the closure vision been developed in consultation with internal and external stakeholders?
Does the closure vision match company, community and government needs, expectations, capacity and capability, and will it be a closure vision that the future landholders support when the company has exited?
Is the vision feasible?
Have site-specific closure objectives been developed for each mine domain?
Do the planned closure activities correspond to the closure objectives?
Are the closure objectives measurable?
Are the closure objectives achievable in a timely and cost-effective manner?
Are the closure objectives feasible?
Are the closure objectives compatible with the closure vision and closure principles?
Have the closure objectives been developed in consultation with internal and external stakeholders?

Tool 4	Screening alternatives for repurposing

A clear definition of the post-closure land use greatly facilitates closure planning. When the post-closure land use is understood, it aids not only the definition of the closure vision and site-specific closure objectives, but also the selection of closure activities and the definition of success criteria.

Understanding and planning for post-closure land use is challenging. The possible and desired post-closure land use will be informed by several factors, including:

— location of the assets (remote locations versus locations close to population).

— pre-mining land use and the historical, current and future use of surrounding lands.

— permanent alterations to the landscape generated by mining activities.

— land capabilities (defines feasible land use).

— regulatory considerations/obligations (may set requirements for post-closure land use).

— the socioeconomic context, including the desires of the community and other external stakeholders; this includes the context as it evolves over time – pre-mining, during mining and post-mining.

— land ownership – in many cases the mining company is leasing the land, and the owner may dictate future land use if any.

— compatible with long term management/ maintenance requirements.

— economic feasibility.

— regional plans.

Relinquishment (transition of ownership and responsibility for the land to a third party) is often discussed in the context of post-closure land use. The type of post-closure land use that may facilitate relinquishment, and the compatibility of land use options with relinquishment, should be considered throughout the planning process.

Post-closure, mined lands may be returned to pre-mining land use. This is not always desired or possible, due to alterations of the landscape and socioeconomic context, but should be evaluated. A wide variety of alternative uses for mined lands is available. These could include adapting post-closure landscapes for forestry, agriculture or wildlife habitat, or use of land as recreational areas.

Some post-closure land uses have the possibility of generating economic benefits. 'Repurposing' is a term often used to refer to activities that have the possibility to generate income from closure activities. This may facilitate transfer of the site to a third party for relinquishment or provide an offset for ongoing post-closure operating and maintenance costs.

There is no single process to plan for post-closure land use. However, there are a number of principles that can be used to identify and evaluate closure options:

— **Evaluate early:** As post-closure land use will inform all aspects of closure, it should be taken into consideration from the earliest stages of closure planning. Formal structures for post-closure land use management and community and business initiatives should be considered from the early stages in approval and permitting, and in place before closure. Sufficient time needs to be allocated for local capacity building.

— **Use the knowledge base:** The information collected, organised and continually updated in the knowledge base will provide part of the basis for identifying and evaluating post-closure land use options.

— **Consider land capability:** The land use needs to be compatible with the suitability of the land to sustain a type of land use permanently (ie soil types, depth, gradient, etc). Post-closure land use will not be uniform over the entire site and will be affected by the post-closure configuration of the mined lands and waste disposal areas.

Good practice: Develop maps of the post-closure landscape and evaluate post-closure land use for areas with common capability. At the earlier stages of planning, these may be relatively large/coarse blocks of land and broad categories of land capability. As closure planning reaches more detailed levels, additional detail on land capability may be added as required. For example, in the early stages a large area may be identified as suitable for agricultural use post-closure, and at the more detailed planning stages, this area could be subdivided into different types of agricultural use depending on capability.

— **Involve stakeholders:** Developing the post-closure land use plan provides one of the most important opportunities to involve stakeholders. Further, a post-closure land use that has been developed with stakeholder consultation and input will be far more likely to succeed. Engage with regulators and other stakeholders including Indigenous Peoples, government agencies, community organisations and private landowners to obtain input on the potential land use options within the bounds of predicted land capability/suitability and company capacity.

— **Map the potential land use options:** Map potential land use for the various mining areas based on the above assessments (considering both the capability of the land and the input from stakeholders).
As the mine approaches closure, this map should become more detailed to include post-closure landform designs, surface drainage designs, land capabilities, landscaping designs and key features.

Case Study

Pioneering sustainable transition to post-closure (Teck)
Teck's Sullivan mine near Kimberley, British Columbia, Canada operated for almost 100 years, and employed nearly 3,500 people at its peak – more than half of Kimberley's population.

The city of Kimberley is now a tourism and recreation destination, and Teck-owned lands were turned over to the city to expand the local ski hill and recreational resorts. In addition, through a collaborative partnership, a community solar power plant was completed and began operating in 2015 on reclaimed land at the Sullivan site.

Teck focused on the inclusion of the local community and Indigenous Peoples in planning for post-closure land use. At the Sullivan mine, Teck started engaging with communities as early as the late 1960s to co-create strategies that would mitigate the economic impact of the pending closure. This included career transition planning and training opportunities for employees, the formation of a multi-stakeholder committee to provide community input into closure planning and transitioning from mining to a tourism-based economy. Rehabilitation after mine closure included tree replanting, water collection and water treatment system enhancements.

Solar project and ski slope developed on reclaimed Sullivan mine in Canada

- **Look for beneficial uses:** Repurposing approaches have the potential to benefit mining companies and stakeholders. While not possible for all sites, repurposing options should be identified and evaluated, starting from the earliest stages of closure planning. Tool 4: Screening alternatives for repurposing provides an approach for the screening and evaluation of repurposing alternatives.
- **Be adaptable:** While post-closure land use will inform many aspects of the closure plan, it is important to realise that the post-closure land use may evolve due to several factors. For example, the opinions or desires of stakeholders may evolve over time, especially for mines with a lifespan that bridges a generational change. Also, innovative approaches may be developed or identified that modify the planned land use.
- **Consider the legislative framework:** Some jurisdictions may have stipulations around post-closure land use or may have regional planning/policies that should be considered for the development of post-closure land use. This extends to the legal framework around title transfer and relinquishment to third parties.
- **Identify and address failure mechanisms:** Not all attempts at repurposing or transitioning assets have worked. It is important to consider in the evaluation of options 'what could go wrong' and develop plans to address this.

Some successful examples of repurposing to provide economic benefits following closure include establishing a solar farm on closed tailings areas, using rehabilitated areas to support agriculture and developing parkland or visitor attractions (see Teck's, Newmont's and Orano's case study examples on alternative post-closure land uses). The post-closure land use plan should continue to be reviewed and updated throughout the LoM.

Case Study

Gold mine turned botanical garden is first of its kind in Indonesia (Newmont)

In 2011, after planting hundreds of thousands of trees on a former mine site in Southeast Minahasa, PT Newmont Minahasa Raya (PTNMR), Newmont's Indonesian subsidiary, delivered 443 hectares (1,095 acres) of revegetated land to the Government of Indonesia. Today, the area is a thriving forest of mahogany, teak, nyatoh and sengon trees, and the future site of Indonesia's newest botanical garden.

Reforestation of the former PTNMR mine area, as well as several other initiatives to improve the long-term environmental, social and economic landscape of Southeast Minahasa, demonstrates how responsible mining and closure can result in long-term benefits to local communities. The reforestation strategy was incorporated into PTNMR's closure plan and Sustainable Development Program very early in the mine's lifecycle. Over time, it evolved to include working with the Ministry of Forestry to designate 221 hectares (546 acres) of the forest as a botanical garden.

Seeking botanical garden designation is long and arduous process, requiring approvals and endorsement from various local governments, as well as research and analysis to assess a botanical garden's potential social, economic and environmental impacts. Working collaboratively with the Department of Forestry, the Indonesian Institute of Sciences, the University of Sam Ratulangi, the North Sulawesi Sustainable Development Foundation and other local constituents, PTNMR succeeded in earning botanical garden designation for the former mine site in 2014.

Both the reclaimed forest and botanical garden have the potential to create positive economic and environmental conditions for local inhabitants. In addition, the site's botanical garden designation ensures the habitats of hundreds of species of plants, birds, insects and other animals will be protected.

The reclaimed forest also has become a model for carbon absorption – the first of its kind in Indonesia. And because of their rich biodiversity, the forest and garden are expected to serve as an outdoor classroom and laboratory for environmental research and education.

PTNMR rehabilitation in Indonesia now a botanic garden

Case Study

Former mining site hosts a leisure centre with a fishing lake (Orano)

The former mining site of Puy de l'Age (Bersac-sur-Rivalier) in France today hosts a leisure centre with a fishing lake. The former mining site was remediated from 1992 to 1996. Each operation was carried out in compliance with the environmental standards in force, in coordination with the regional department for the environment, town and country planning and housing and in consultation with local populations.

The lake was created by impoundment of the old open pit mine, with reprofiling works especially adapted to meet spawning requirement of the fish introduced after the remediation. The rest of the site has been revegetated as grassland. The site is now home to a diverse fauna and flora.

The site was monitored until 1999. The measurements carried out showed an absence of any environmental or health impact, and all inspections ceased on the Puy de l'Age site by prefectural order 99-266 of 17 May 1999.

The Puy de l'Age lake is private and is now used as a recreational area, especially for fly-fishing.

Mining method

- In operation from 1977 to 1993
- Underground mine workings
- Open-cast mines

Production

- 216,000 tonnes of ore extracted
- 421 tonnes of uranium produced

- Remediated from 1991 to 1996

- Fish introduced into the impounded open-cast mine workings and lake profile adapted for spawning

- Recreational zone devoted to fishing

Puy de l'Age before closure and post-closure

Key questions to ask about planning for post-closure land use

Has there been engagement on post-closure land use with external stakeholders and meaningful incorporation of feedback?
What is the landownership situation, including formal and customary landownership aspects? Are there legal restrictions on post-closure land use options?
Are there foreseeable socioeconomic or regulatory changes that will affect post-closure land use?
If repurposing is pursued, how will revenues/landownership be addressed? How can the mining company evaluate the business case for repurposing, including capital investment (beyond that needed for closure), project evaluation and management?
Have you explored or made opportunities to support, encourage, lead on and/or participate in developing regional land use, watershed use and/or socioeconomic regional planning (strategies)? Consider sectors such as agriculture, tourism, renewable energy, and industrial and other types of natural resource development (forestry, hydro, gravel/sand – development minerals).
Is the post-closure land use compatible with relinquishment? How will residual liabilities be managed?

Engagement for Closure Plan Development

06

Tool 5	Key messages for social transition
Tool 6	Social transition activities checklist

Effective mine closure planning and implementation considers the views, concerns, aspirations, efforts and knowledge of internal and external stakeholders to identify mutually beneficial closure outcomes for the company and its host communities. Stakeholder engagement serves as a critical aspect of managing social risks of closure. Many jurisdictions and companies require some level of stakeholder consultation during the design of the closure plan.

Opening the closure planning process and getting local community members and other stakeholders meaningfully involved in decisions on mine closure, including feedback on the closure vision, objectives, measures and criteria, can lead to more beneficial outcomes for the mining company and external stakeholders. Engagement on closure should take place throughout the mining life cycle and at the right time, with a strategic approach that involves and empowers the local community in the decision-making process.

For mines that have tailings storage facilities, ongoing engagement with those stakeholders with tailings related governance roles, as outlined by the Global Industry Standard for Tailings Management (GISTM) will be required. Engagement with both tailings governance and closure governance practitioners will help to ensure the safe closure of tailings storage facilities. **Tool 10: Considerations in developing closure activities for domain specific issues** provides a summary of key closure-related responsibilities of various roles in the tailings governance framework.

External stakeholders, the local community in particular, have a central role in planning for closure and realising the social transition at the end of mining and developing success criteria for closure. It is the local community members who will experience mine closure and ultimately determine whether the closure plan and social transition has been successful.

Good practice: Involve key affected stakeholders in the closure plan development, and keep broader external stakeholders informed and updated on progress. Leaders, including government and traditional or indigenous community leaders, should be engaged in the development of the plans as the ultimate aim for community members and relevant government stakeholders to develop and take ownership of outcomes of closure.

Identification of stakeholders

The involvement of stakeholders is key to the success of the closure plan and social transition after mining. In developing engagement programmes, it is necessary to identify the appropriate external stakeholders. ICMM's *Community Development Toolkit* provides useful tools on identifying stakeholders.

Sustainable mine closure is a shared endeavour, requiring collaboration between industry, communities and governments to understand and address the environmental, social and economic aspects of closure. In support of this, representative stakeholders must be identified and engaged. The Upper Hunter Mining Dialogue case study provides an example of a multi-stakeholder engagement process.

The stakeholders identified will be involved in activities such as social transition planning, as well as developing a vision, planning for economic diversification and discussing community development plans. While identifying stakeholders, the company will need to also assess the capacity and capability of people who want to be involved, and training requirements. For example, if the local government is to take ownership of planning and implementation of social transition initiatives, it will need to have the capacity to manage budgets.

The following is a list of key external stakeholders and how they might be involved in the closure and social transition planning process. This list is not exhaustive and should be built upon to reflect the influential and impacted groups within the mine's zone of influence.

Community

— The communities within the mine's zone of influence, which may be extensive, are those that will be directly impacted by the mine closure process. These communities should be identified early in the permitting process. The promotion of community engagement and involvement in all aspects of the social transition process is good practice, including in discussions on future land use and social investment.

Good practice: Ensure that community members participating in the social transition planning process are not limited to elected leaders, but include informal and traditional representatives of women, youth, community associations, vulnerable groups and under-represented minorities. Public forums and other broad engagement opportunities can be facilitated so that consultation is robust, and input does not reflect only the majority view.

Indigenous Peoples/First Nations/traditional owners

— In some jurisdictions, Indigenous Peoples will be present in the zone of influence and may have rights over the land separate from mining rights. There is an additional level of consideration to be given to properly address the rights of Indigenous Peoples and recognising these rights even where they are not fully enshrined in the dominant regulatory structure of the jurisdiction. At a minimum, there is an additional onus to consult early in the planning process, and to recognise that these groups may have a much deeper connection with the land than more recent arrivals. For further information refer to *ICMM's 2015 Indigenous Peoples and mining: good practice guide*, second edition.

Workforce

— Engagement with mine employees to understand their concerns and visions for the future should be undertaken to assist companies in identifying appropriate opportunities in supporting employees to have a successful employment transition. The workforce and representative unions should be kept aware of the planned LoM, as well as retrenchment/downscaling associated with the cessation of operations. This will ensure that unrealistic expectations at closure are mitigated, thus minimising potential social unrest.

— Employees can also act as ambassadors for the closure process when engaging with other employees or external stakeholders.

Governments and regulators

— Its input on mine planning and design, future land use and social investment can be useful to making sure the social transition plan aligns with and builds on existing processes and priorities for land use and development in the area.

— Government plans may need to integrate consideration of, for example, loss in tax revenue, utilities and community services when the mine closes.

— Regional and local government representatives may provide input and support on elements related to the regional and local economy and aspects related to the regional development plans, or other sectors over which they have jurisdictional authority, such as health, education and transportation. Regional and local land use strategies or economic growth priorities may exist and should be integrated into the planning for social transition at closure. The mining company must work with local authorities to make sure they understand the impacts of mine closure and how that will impact their development agendas and plans (eg they may choose not to complete capital works if there is a likely decline in population or change in community profile).

— Engagement with regulators on the mine closure process ensures they are aware of the measures the mining company is taking to address any requirements related to public participation.

— Identification of government stakeholders should consider non-regulatory bodies, such as conservation authorities or similar; boards, such as education, health, economic development, energy (renewables or other); and cooperatives and associations, such as those for tourism, agriculture and natural resources (eg forestry, fisheries, gravel/sand/aggregate).

Industry peers

— Other current or planned mineral development projects in the region could represent alternative economic drivers for the local community, which would inform the social transition for mine closure. Other mine operators could also represent new partners for the mining company as they may be open to collaborating on regional planning exercises that would support social transitioning, as well as opportunities for repurposing or transitioning land and infrastructure.

Good practice: The presence of other mining projects is important to the external message. Where possible, mining companies should engage with industry peers to develop cohesive messaging on impacts and opportunities from mining, and their commitment to sustainability post-closure. There is an emerging trend for mining companies to share experiences with social transition, recognising the value in learning from their collective experiences. This type of transparency and openness is fostering a community of best practice that will lead to better outcomes for companies and communities.

Community engagement for the Quellaveco project

Other sector contributors

— The social transition for mine closure will be informed by other economic drivers in the area that may offer opportunities for diversification of the local workforce and businesses or may have use for redundant infrastructure, or alternative post-mining land uses.

— International or national NGOs can provide insight and resources on large-scale development needs and opportunities. Local NGOs often have a unique understanding of and an existing relationship with local stakeholders. They can therefore serve as partners in implementing social transition, including helping to mobilise community involvement in the social transition planning process, social monitoring throughout the mine life, implementing capacity-building programmes that will be supported through the mining company's social investment programmes, and communicating the company's progress with closure.

— It is expected that as part of the social transition for mine closure, 'ownership' of social investment programmes will transition from the mining company to the communities, government and potential other partners, which is intended to ensure continuity and ongoing positive impact.

Academia

— Trade schools, colleges and other training institutions can play a role in providing capacity-building initiatives that support the local communities in preparing for and maximising opportunities throughout the social transition for mine closure.

— Academic research or publications relevant to the closure planning and social transition, such as studies on economic or population trends, development patterns and priorities, social dynamics, governance capacity, etc, can assist in informing the closure planning process.

Media

— Local media can be an important vehicle to share information on mine closure and promote participation in community engagement efforts.

Engagement on closure vision and post-closure land use

The local community should be involved in the development of the closure vision and development of post-closure land use. Involving the community in this process may take many forms, and different techniques are used in different cultural contexts. Meaningful participation is critical to ensuring the local community's ownership of the results. Upfront work is needed on the part of the mining companies to guide the conversations and provide examples of realistic options

Case Study

Engagement for the Hunter Valley region, New South Wales, Australia

The Upper Hunter Mining Dialogue (UHMD) provides an example of a multi-stakeholder engagement process. The UHMD was established by the New South Wales Minerals Council in response to community concerns around the cumulative impacts of mining operations within the Hunter Valley region in New South Wales, Australia. Industry realised that the concerns raised were not specific to any one site and would need a collective response. Eight coal producers in the region engaged directly through the UHMD with community, environmental and business groups, as well as local government.

Issues addressed by the group included the closure impacts and what alternative land use options could be implemented to sustain the local communities after mining. Through stakeholder engagement, the UHMD has been instrumental in developing a vision of how the Upper Hunter will look post-mining.

The UHMD encouraged appropriate ministries to update the Synoptic Plan: Integrated Landscapes for Coal Mine Rehabilitation in the Hunter Valley of NSW that had been developed in 1999 by the New South Wales Department of Mineral Resources and that was out of date. As a result, the Department of Premier and Cabinet is leading a 'whole of government' approach to reviewing the plan with other relevant government departments. The UHMD is a key member of the working group and has supported them with stakeholder identification.

The UHMD has built a venue for multi-stakeholder dialogues, and generated trust and support with communities, the government and mining companies. Through the UHMD, community issues have been identified and addressed.

Some of the key learnings from the UHMD for multi-stakeholder engagement on closure are:

— ensure the right people are at the table, to enable equal opportunities to participate and share solutions to be implemented – this should include mining company representatives with adequate decision-making authority, supportive voices and potential opponents

— provide information with an honest and balanced view

— present monitoring results and information in a way that is understandable for local community members

— provide clarity on issues of concern to avoid potentially incorrect assumptions

— update and revise regional plans on a regular basis (± five years) to consider changes in the market, technology and policy – these changes may affect decisions related to alternative land uses

— communicate updates so that people know that work is progressing

— engage all relevant government departments in planning so that all government plans are consistent.

for post-closure land use, considering both technical and economic feasibility. The timing of the engagement will also shape the discussion, with assessments likely to be less in depth in the earlier stages of engagement. Tool 5: Key messages for social transition and Tool 6: Social transition activities checklist provide guidance for key messages to share with stakeholders during the different stages of the LoA and corresponding activities to undertake.

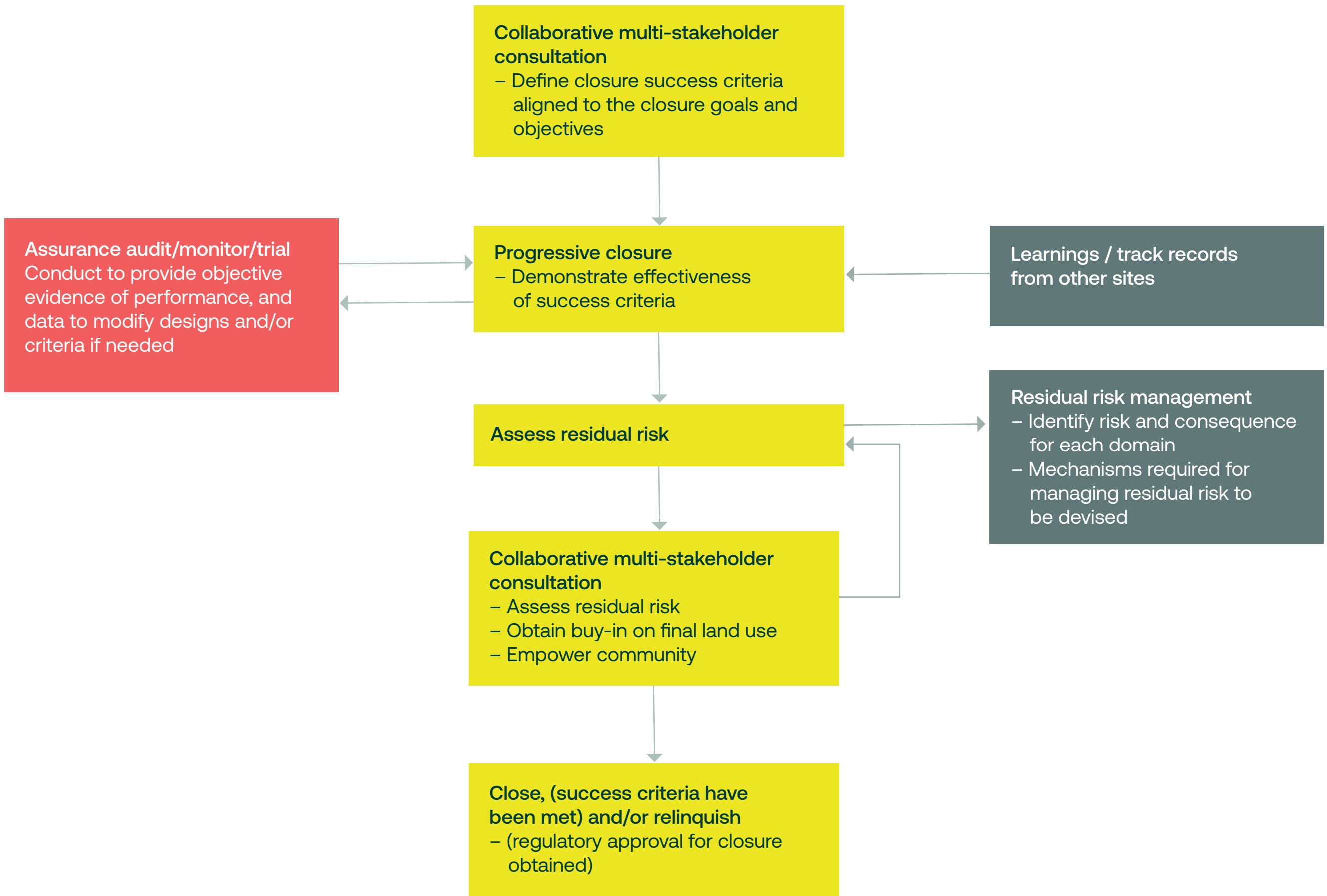
While some jurisdictions may facilitate effective development planning exercises, most local communities will not have a recent, comprehensive document outlining their vision for long-term development. In such cases, the company may choose to support a process to help the community articulate its development priorities. This process can be facilitated by a qualified non-governmental organisation (NGO), government official or external consultant. In some cases, the company may suggest and support a broader regional planning process that provides a detailed map of economic growth patterns and opportunities. While these broader planning processes would require collaboration with multiple parties, they have the potential to yield more useful results and can be capacity-building opportunities for the local communities involved.

Engagement on success criteria

Early and ongoing engagement with regulators and other external stakeholders should be part of the development and refinement of success criteria (see section 9 for further information on success criteria). Ongoing agreement on applicable criteria will facilitate success of closure outcomes in general and of relinquishment in particular.

Figure 4 illustrates the success criteria engagement process and how learnings from progressive closure can be incorporated into the refinement of these. Equally important, this figure identifies the role of residual risk identification and management in all cases. Residual risks may remain, and these should be clearly communicated and understood. Engagement on success criteria therefore also needs to include engagement on residual risk.

Figure 4: Developing Success Criteria



Identifying and Assessing Risks and Opportunities

07

Tool 7	Climate change and mine closure concerns
Tool 8	Risk/opportunity assessment and management

Risk and opportunity assessments are deeply embedded in the management of many aspects of mining, with well-established tools and methods for the identification and evaluation of risks and opportunities. The intention of using these tools is to minimise risk and maximise opportunity.

Greenhills operations, Canada

There are numerous potential management benefits to embedding a structured risk/opportunity assessment process in closure planning. These include:

- attention and resources focused on the risks and opportunities that are most important.
- identification of potential closure cost savings.
- closure objectives that are appropriate for the identified risks.
- establishing metrics for success criteria.
- development of appropriate closure activities so that the identified risks are mitigated to an acceptable level.
- communication of key risks within an organisation and to stakeholders.
- opportunity to engage a range of stakeholders in the closure process.
- considering the design life of any engineered systems or features that would require ongoing maintenance or future replacement.
- understanding and communication of residual risks that will remain after implementation of closure activities, facilitating relinquishment.
- improving likelihood that opportunities for lasting benefits are identified and put into action, including opportunities for alternative post-closure land uses.

Given these benefits, it is good practice to embed risk assessment in closure management, with a formal risk assessment conducted and documented early in the closure planning process and revisited periodically as the closure plan evolves. Identified risks should be used as a management tool, as a basis for setting out tasks and accountabilities for both preventing and mitigating risks.

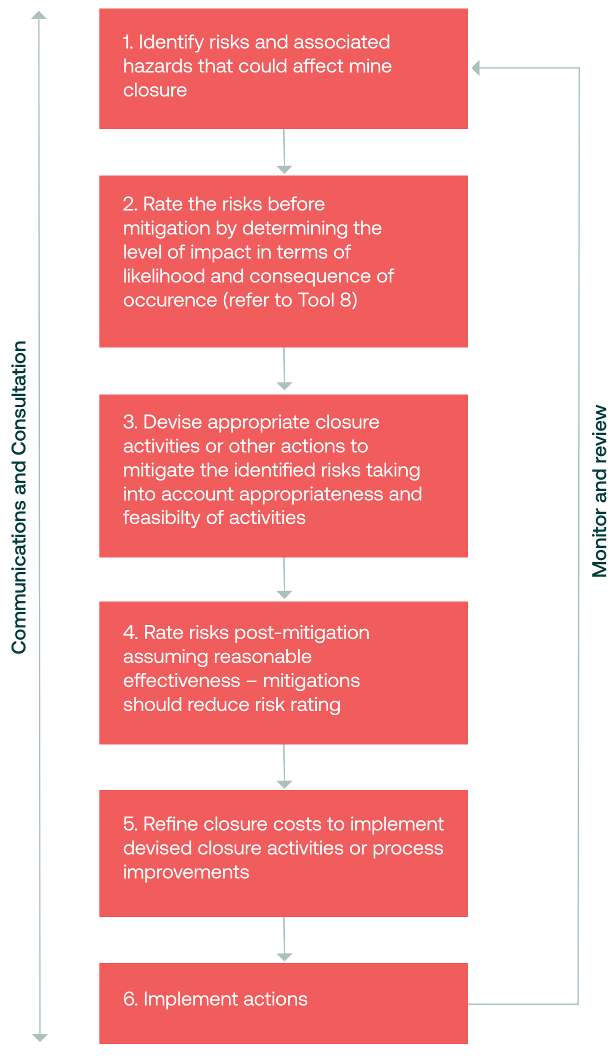
Figure 5 illustrates the key steps to be taken in identifying risks as part of the closure planning process. The risk assessment process should be undertaken on a regular basis incorporating changes to the knowledge base such as changes in the mine plan, research results, learnings from progressive closure, monitoring data and input from ongoing stakeholder consultation.

This risk assessment should consider several different types of risk, associated with various categories of consequences. Categories typically used in current practice may include the following:

— **Health and safety:** impacts on the well-being of people (injuries, loss of life, as well as benefits such as better access to medical care, improved contractor safety practices, etc).

— **Legal and regulatory:** consequences associated with non-compliance with regulatory statutes, including warnings, fines, legal actions and imprisonment.

Figure 5: Risk Assessment Process



— **Environmental:** impacts on air, soil, water, and ecosystems, as well as opportunities such as habitat creation and biodiversity improvements.

— **Social:** impacts on the well-being of the communities within the zone of influence of the mine, including the workforce and cultural heritage, as well as the business risk associated with workforce uncertainties (ie safety and financial liability impacts).

— **Financial:** impacts on the mining company measured in financial terms, including opportunities for cost savings/offsets.

— **Reputational:** impacts on the reputation of the mining company, including the social licence to operate at the site in question and other sites, and opportunities to leave a positive legacy post-mining.

When undertaking the risk assessment, cumulative impacts or risks should be considered, along with opportunities. For example, risks considered in isolation may have low consequences, but when considered in the context of multiple mining sites and industrial facilities in a given area producing similar impacts, the risk to the company, environment, and community may significantly increase. Approaches to managing and mitigating cumulative risks and opportunities may also significantly vary from approaches for these risks in isolation, resulting in potential greater closure costs or lesser benefits if not properly captured during the initial risk/opportunity assessment.

— One of the areas of risk evaluation where practice is evolving rapidly is the consideration of climate change impacts on closure and long-term planning. **Tool 7: Climate change and mine closure concerns** provides an overview of the current state of addressing climate change risk in mine closure, and indication of additional recommended resources.

For the largest risks, the critical control management (CCM) process provides a practical approach to providing control over large or potentially catastrophic events that are identified through the risk management approach. The CCM approach provides clarity on the controls that matter most for such events, with a balanced approach to both preventative and mitigative measures. Clear guidance on CCM can be found in ICMM's *Critical control management: implementation guide*.

Key questions to ask about the risk/opportunity assessment

Does the assessment capture the categories of risk that are important to the mining company and stakeholders?
Were the right team members, representing the needed mix of disciplines, involved in identifying and ratifying the risks and opportunities?
Was all relevant available information used to assess the risks, including input from external stakeholders where applicable?
Are there data gaps that need to be addressed before risks can be adequately assessed?
Have risks related to unplanned and temporary closures been considered?
Have potential cumulative risks been assessed?
Has a stochastic (probabilistic) assessment of risks been considered?
Should success criteria or closure activities be refined based on the risk assessment?
Are residual risks compatible with relinquishment and/or the identified post-mine land use, and do all stakeholders understand the residual risks?
Have risks been assessed both with all controls in place, and in the case where the controls fail?
Have risks that could appear post-closure been included in the evaluation?
Have the strategies been identified to mitigate the consequences of any risks eventuating post-closure, and are measures being put in place to deal with these consequences?

Many mining companies have their own risk assessment tools. In the absence of an 'in-house' standard, Tool 8: Risk/opportunity assessment and management provides a risk/opportunity assessment process based on the risk management standard developed by the Council of Standards Australia and the Council of Standards New Zealand, AS ISO 31000:2018 Risk management – guidelines. This tool is applicable to evaluating mine closure risks, as are many other risk evaluation tools in use by ICMM members.

Sishen mine open pit, South Africa

Closure Activities

Tool 9	Considerations in developing closure activities for transversal issues
Tool 10	Considerations in developing closure activities for domain-specific issues

Closure activities are the physical works carried out to close the site. These may be done during operations (progressive closure) or in the closure and post-closure period. Closure activities are undertaken to achieve specific closure objectives and satisfy success criteria.

For example, a closure objective may state that buildings on the site should not pose a safety hazard post-closure. The appropriate closure activity to achieve this may be demolition of the site buildings, with the remnants either recycled or disposed of in a landfill. This section presents approaches that are used to evaluate alternative closure activities and choose the option that will be implemented to achieve the objectives in the short and long term. For more detail on the technical aspects of measures that are typically used, please see **Tool 9: Considerations in developing closure activities for transversal issues** and **Tool 10: Considerations in developing closure activities for domain-specific issues**.

At the simplest level, the closure plan provides a description of the closure options that will be implemented for each domain that makes up the mine. The cost of carrying out these closure activities is the basis for any estimate of the overall cost of closure.

For a given closure objective, there may be many feasible closure activities. The selection of closure activities at the site may be informed by the following:

- risk assessments (which may also inform the definition of objectives).
- stakeholder input.
- chemical and physical assessments.
- engineering designs and optimisations.
- formal trade-off studies, multiple accounts analysis and cost analyses (including life- cycle cost analysis).
- resistance to climate change.
- the results of research studies and learnings from progressive rehabilitation.
- regulations or regulatory commitments (such as those made during the environmental impact assessment process).
- standard industry practices (eg it is typical to demolish and remove all buildings that will serve no purpose following closure).
- residual resourcing opportunities.
- value of remaining assets (land, water rights, infrastructure).

Similar to the development of other projects, the level of design detail for closure activities usually evolves over the mining life cycle. At the earliest stages of closure design, measures are typically conceptual, and it is common to carry forward several different conceptual closure activities for a given area. It is typically necessary to identify an option from the earliest stages as the most likely to succeed and integrate the cost estimate for that option in the overall site closure cost estimate. Many companies can utilise their capital projects framework for the evaluation of closure activities.

As the closure plan matures, designs are refined, options further assessed, stakeholder input gathered, trials conducted and definitive measures established. Research, engineering studies or experience with progressive closure may be used to inform the selection of closure activities and provide greater confidence that the selected measures will provide the desired outcomes. For instance, active water treatment may be considered to manage impacted water at a site in the early design stages. As site-specific testing is carried out, it may be demonstrated that passive treatment options will be effective, or that source controls can eliminate the need for treatment altogether.

Not all closure activities will be subject to the same level of evaluation. Some will be relatively standard and will not require significant consideration of alternatives or may be a binary choice between simple alternatives (eg demolish or do not demolish). In other cases, there may be many alternatives considered, with significant differences among the options in terms of cost, social acceptance, effectiveness, opportunities, risk profile and other factors. In these cases, final selection of the appropriate closure activities may take years of effort, involving input from stakeholders, research programmes, design studies and specific risk evaluations. The use of multi-criteria alternatives analysis to evaluate closure activities is good practice to compare benefits and understand trade-offs when identifying the most appropriate closure activities for the site. The ICMM *Tailings Management Good Practice Guide* section 3.3.4 provides detail on these approaches including multiple accounts analysis.

Open pit backfilling at Marlin Mine, Guatemala

The general approach for evaluating closure activities is as follows:

— A preliminary 'long list' identifying potential closure activities is generated. This list is typically developed based on several inputs, including professional experience, literature reviews and stakeholder input.

— An initial screening to eliminate options that are not feasible, either on their own or in combination with other measures. Formal 'evaluation parameters' may be established at this stage, which are quantitative or qualitative considerations used to evaluate the options under consideration. For example, social acceptability would likely be a qualitative parameter, while cost would be quantitative.

— The options that have been eliminated in the screening should be documented, along with the rationale for their elimination. This documentation helps ensure that decisions are traceable and facilitates coming back to 'long list' options if conditions change.

— Of remaining options, screening-level engineering designs or technical evaluations may help quantify the evaluation parameters, such as cost or value. This information can be used to further narrow the list of options. Depending on the number of options, designs may be advanced to a conceptual or pre-feasibility level to further screen out alternatives.

— Where multiple options remain at this stage, a multiple accounts analysis[1] may be used to compare and rank options. While cost-benefit analyses are useful, a multiple accounts approach is commonly used in closure design as a way to incorporate disparate elements such as cost or value, environmental impacts, social acceptance and technical risk, among others.

— If a multiple accounts analysis is used, the options assessed will be ranked. It is important for the scoring and weighting approaches to be well documented as the rankings will be a direct result of these.

— At the completion of a multiple accounts analysis, sensitivity checks should be carried out to evaluate the extent to which rankings are affected by credible ranges for either the inputs or the weightings placed on different parameters.

— Formal risk evaluations may also be carried out on closure alternatives to demonstrate their effectiveness at risk reduction in various domains.

Many variations on the above process are possible and it will be necessary to adapt to site-specific conditions and the complexity of available alternatives to meet closure objectives. The sophistication of the evaluation process used should be commensurate with the cost and complexity of the measures under consideration. The level of effort will be dependent on the complexity of analysis; best practice is to perform the analysis in stages. This process should be supported with ongoing updates to the relevant stakeholders (both internal and external) regarding progress and status to ensure timely response to concerns and maintain engagement.

A formal project management approach is recommended when completing closure activities due to the magnitude of costs associated with closure.

1. A multiple accounts analysis (also known as a multi-criteria analysis) establishes two or more 'accounts' that are weighted based on a qualitative and transparent assessment of their relative importance to the decision. Various options can then be rated on a numerical scale in each account, and a weighted total calculated for the option. There is no limit to the number of 'accounts' that are used. Typical accounts include cost, environmental impacts, social impact and technical risk.

Success Criteria

09

Closure activities are implemented to meet specific closure objectives. Success criteria are the specifications, measurements or requirements that, if met, denote the success of the closure activities in meeting closure objectives (also sometimes called 'closure criteria').

Rehabilitated site at Damang mine, Ghana

As an example, an objective might be to prevent an acidic seep from impacting water downstream of a mine waste facility, and the closure activity implemented could be a passive treatment system. One of the criteria to demonstrate that this measure is satisfying the objective could be that discharge concentrations from the passive treatment system are maintained within a defined range, such as a pH between 6 and 9.

Meeting success criteria is a concrete way to demonstrate that the closure plan has been executed effectively, assuming the correct criteria have been selected. It is usually necessary to demonstrate that success criteria have been met before the associated financial assurance will be released (where applicable), or relinquishment considered. Success criteria developed specifically to facilitate the relinquishment (legal and financial) of a property are often called 'relinquishment criteria'.

The SMART approach (specific, measurable, achievable, relevant, timely) is useful for developing and assessing success criteria. Key considerations for each element of SMART criteria are as follows:

— **Specific:** Criteria should relate directly to closure objectives and individual closure activities. A closure activity or group of closure activities without an associated criterion indicates a gap; a criterion without an associated measure or measures may indicate the criterion is too general.

— **Measurable:** If a criterion cannot be measured, there is no way to demonstrate to the regulator or stakeholders that it has been met. While the method of measurement is usually obvious for numerical criteria (such as concentrations or discharge flow rates), narrative criteria may require alternative forms of measurement (such as completion of a given task as confirmed through as-built drawings or field inspections). Some objectives may require a combination of qualitative and quantitative measurement.

— **Achievable:** If relinquishment or return of financial assurance is to be attained, it is critical that the criteria are realistic and can be achieved. Unrealistic or poorly defined criteria can delay or prevent relinquishment, or unnecessarily extend monitoring periods.

— **Relevant:** Criteria should ultimately be aligned with closure objectives and the social, environmental and regulatory context of the site.

— **Timely:** Criteria will have a time component, either explicitly or implicitly. Some can be considered completed immediately after implementation of the associated closure activities while others will require a period of monitoring. For the criteria that will require a monitoring period, it is important to clarify early in planning how duration of monitoring will be defined.

In addition to the standard SMART approach, the underlying fundamental element in closure is success criteria are 'agreed'. Success criteria that do not have the agreement from the regulators and other external stakeholders are not meaningful. To ensure agreed criteria are developed, it is preferable to engage on them early in closure planning, with full documentation of agreements on applicable criteria. These agreements and approvals are especially important if attempting to develop a clearly defined pathway to relinquishment.

Good practice: The setting of the success criteria should be done with inputs from multiple disciplines across the operation. Involvement and understanding of the targets by the local community and regulators should also be secured for ongoing alignment and agreement on the endpoint for mine closure.

Some success criteria may be relatively simple to define and can be clearly established at the earliest stages of closure planning. As an example, regulatory limits often provide clearly predefined success criteria. Finalising other criteria will require study and research and may require agreement on post-closure land use. This means that criteria may not be finalised until the final closure plan is developed.

Criteria development may require site-specific studies and research plans. For example:

— Multi-year revegetation studies to refine the planned approach to rehabilitation and applicable success criteria are common.

— Discharge criteria for impacted mine waters may require studies for development – these studies could address a range of topics, including ecosystem characterisation, evaluation of assimilative capacity, anti-degradation standards and mixing zones, etc.

Where the interactions are complex, and longer-term studies are required to develop criteria, it is common to start closure planning based on conservative criteria, which are then refined as information is obtained from research.

Some criteria will be highly dependent on the post-closure land uses. For instance, water quality criteria may be quite different if the closure plan anticipates that water may be used for agriculture or as an input to aquatic ecosystems. In many jurisdictions, both water and soil quality criteria are explicitly related to land use in the regulatory guidance, with different criteria applicable to industrial, agricultural and residential uses. This means that changes in planned land use may change the applicable criteria.

The continual refinement of success criteria over time highlights the iterative nature of closure planning, and the importance of ongoing monitoring and review. Changes in the planned post-closure land use can drive changes in criteria. While criteria are designed to evaluate the success of closure activities to meet closure objectives, changes in criteria may also drive changes in the closure activities. For instance, where an objective has been defined to avoid adverse impacts on a downstream ecosystem, active water treatment may be selected as the approach that can meet conservative criteria selected prior to the completion of site-specific studies. However, once site-specific studies are completed, it may be possible to secure regulator and stakeholder agreement on less stringent criteria, which may permit a change in the closure measure.

Success criteria are most commonly developed for 'lagging indicators', that is, indicators that demonstrate that the task has been completed in accordance with the objective. However, for managing the closure process, leading indicators can be extremely useful to assess if closure activities are on track for success. Examples of this include all wastes characterised and managed as per the plan as they are generated, and appropriate dumping records as they are being generated.

Key questions to ask about the success criteria

Are the criteria related to the closure objectives? Criteria without objectives or objectives without criteria indicate a gap in the closure plan.
Are the criteria measurable or demonstrable, either through numerical assessment or inspection reports?
Are the criteria achievable in a reasonable time frame? Is the mining company willing to commit to achieving them, and have the appropriate internal stakeholders been involved in making commitments to meet the criteria?
Do the criteria need a specific time frame, for example, meeting water quality over a five-year period?
Have regulators been involved in the development of success criteria or approved them? Is there a clear agreement that meeting the criteria will form the basis for a release of associated financial assurances and/or permit relinquishment? Has this agreement been documented?
Have external stakeholders been involved in the development of criteria? Is there documented agreement with the criteria?
Once success criteria are met, what are the residual risks? Will these residual risks permit relinquishment?
Is it feasible to measure the criteria?
Have success criteria been developed for both leading and lagging indicators?

Progressive rehabilitation at Batu Hijau Mine, Indonesia

Progressive Closure

010

The term 'progressive closure' encompasses ongoing efforts to advance closure activities during construction and operation of a mine.

Progressive closure is the implementation of closure activities during the operating life of a mine. The types of activities that can be implemented as progressive closure are controlled by site-specific conditions and mine plan.

Some of the most common progressive closure works include:

- soil management (eg stripping, stockpiling, placement).
- strategic placement of uneconomic materials.
- diversion of unimpacted waters.
- revegetation.
- stabilisation works.
- cover placement.
- demolition of unneeded infrastructure.
- improvements to water management infrastructure.
- in-pit dumping of waste rock material.
- capping or encapsulation of tailings waste rock material.

In some circumstances, the line between mining activities and progressive closure may blur. For example, where open pits are used for the disposal of mine waste, backfilling activities can be seen as progressive closure (pit filling and stabilisation) or operations (mine waste disposal).

The benefits of progressive closure are well documented. Some of the most important are:

- **Social licence and regulator relations:** Progressive closure provides the opportunity to demonstrate the effectiveness of closure activities at operating sites, as well as the overall commitment to implementing closure. It provides stakeholders with evidence that the proposed technologies are effective and that conditions after the implementation of closure works are satisfactory. This can enhance the social licence to operate not only at the site under consideration, but also at the operator's other mines.
- **Experience/knowledge building:** Progressive closure provides the opportunity to evaluate and refine closure activities at a smaller scale prior to final implementation. This can result in numerous improvements in the closure plan, including risk reduction (due to more certainty in technical approaches), practical experience to inform feasibility of closure activities and cost estimates,

and improvements to definitions of success criteria. Establishing and testing success criteria in collaboration with regulators and other stakeholders helps with the development of realistic, experience-based agreements.

- **Reduction of liability:** Successful progressive closure reduces the extent of disturbed lands, which in turn reduces the total liability as considered in financial reporting, LoM planning and financial assurance. Some jurisdictions provide mechanisms for reducing financial assurance amounts based on the extent of successful progressive rehabilitation. Ideally, this could be tied to progressive relinquishment for areas of the site where closure has been completed.
- **Tax benefits:** In some jurisdictions, there may be a tax benefit with progressive closure. Progressive closure activities are carried out when the asset is generating revenue, and may facilitate tax reduction, but activities carried out after closure typically do not offer the same type of benefit.

All these benefits can be framed as a reduction of risk for the closure plan. Care should be taken to not delay detailed closure planning for sections or domains going through progressive closure works. Implementing measures without having completed detailed studies may lead to higher costs and often long-term residual risks.

An evaluation of progressive closure risks and opportunities also requires consideration of the reasons why progressive closure has not been implemented at sites where it may appear technically feasible:

- **Uncertainty in the mine plan:** While closure plans are developed based on a current mine plan, mine plans typically evolve over time and at any given time there are usually several possible modifications to the plan under consideration. As an illustration, a waste rock facility may appear to be at its final extent and a candidate for cover placement. However, there could be a mine plan update under consideration that would require expansion of the dump. If this change is implemented, rehabilitation effort spent on the dump could be wasted. A building may be a candidate for demolition, but there may also be a viable option under consideration to repurpose it for other mining uses.
- **Competition for limited financial resources:** Implementing progressive closure typically requires expenditure above what is strictly necessary for operations each year. If only financial factors are considered, progressive closure works may not be able to demonstrate a competitive rate of return on investment. Due to the time value of money, a net present value (NPV) analysis may show a strong financial argument for pushing closure works to as late a date as possible. It is important to note that an NPV analysis is not a complete business case and should not be the only factor taken into consideration when assessing progressive closure. In particular, an NPV analysis typically assumes that the scope of an activity will remain static if delayed, which is often not the case with closure.

The business case for progressive closure should account for both the benefits of implementing progressive closure and the possible arguments against it.

Progressive closure and costs

Closure costs can be challenging to estimate correctly and there is considerable industry experience where actual closure costs have differed considerably from estimated values. This potential variation is a risk for the mining company. Progressive closure is one of the most effective means to gain direct experience with the implementation of the closure works and accurately characterise their true costs. Feeding this information back into future cost estimates will reduce the risk of inaccurate estimates.

Implementing progressive closure also provides the opportunity to reduce the total disturbance at any given time, reducing the amount of the financial provision for the company (see case study example on the value of progressive closure at the Rio Tinto operated Diavik Diamond Mine). This can benefit the book value of the company. If the reduction in the disturbance can be translated into a corresponding reduction in the financial assurance held by the regulator, this can reduce the costs associated with the financial assurance. Depending on the form of financial assurance required, this can translate into benefits such as reduced carrying costs or increased availability of credit for other investments.

As shown in Figure 6, there is not just one pathway for the reduction of liabilities through the implementation of progressive closure. A 'standard' programme of progressive closure may result in one level of reduction in the provision whereas a more intensive programme could result in a significantly greater reduction in the provision.

Another financial benefit of progressive closure is in terms of cash flow. Progressive closure is an operational cost, typically incurred at a time when cash flow is positive, while final closure occurs after production, when cash flow for the mine can be expected to be low or negative. There may be benefits to incurring closure costs when cash flow is positive, such as tax benefits in some jurisdictions.

An NPV (or present value) analysis of costs is likely to suggest that progressive closure is more expensive, as the present value of any expenditure will be lower the further in the future it is placed (assuming no change in scope). However, if progressive closure is looked upon as an investment, a more balanced analysis emerges. The returns on an investment in progressive closure typically include both tangibles (improved book value of the asset, reductions in costs associated with provisions, improved cash flow, possible tax benefits, possible reduced carrying costs for financial assurance amounts, greater credit availability) and intangibles (risk reduction, particularly through reduced risk of cost overruns and through improved relations with stakeholders including the likelihood of gaining approval for future projects). Both the tangibles and intangibles should be considered when evaluating an investment into progressive closure.

Tracking progressive closure

The rate of progressive closure and associated costs vary widely according to site-specific circumstances (complexity, climate/rainfall) and regulatory framework. Even at sites where there are opportunities for progressive closure, there may be some years where progressive closure activity on the ground is not possible given the mine plan context or economic conditions.

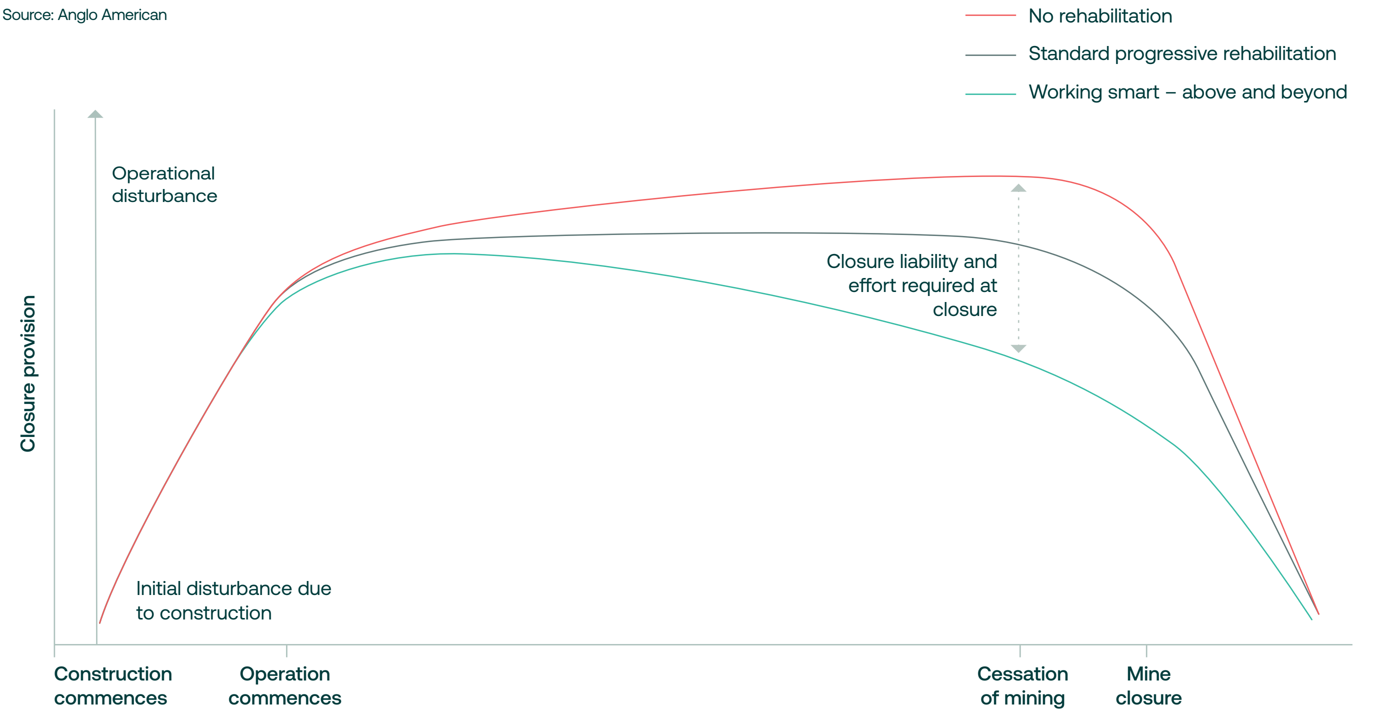
Various kinds of indicators can be used for completed closure work. Some common examples indicating different stages of progressive closure work include:

- project performance (cost and schedule) of scheduled concurrent rehabilitation items.
- completion of rehabilitation work as per plan and quality assurance requirements.
- percentage of salvaged topsoil directly placed.
- area of reshaped waste rock facilities.
- amount of reactive material disposed of according to plan.
- mitigation of identified risks.
- hectares/percentage of rehabilitated land that meet the final rehabilitation success criteria.

In some cases, it may be worthwhile to use performance indicators to establish annual targets or for tracking progress.

Figure 6: Progressive Closure – Opportunity for Liability Reduction

Source: Anglo American



Case Study

Value of progressive closure at Diavik Diamond Mine (Rio Tinto)
The Diavik Diamond Mine is operated by Rio Tinto in the far Northwest Territories in Canada and produces gemstone quality diamonds.

The operations have considered closure since inception in 2003, with closure objectives already agreed by regulators and local First Nations. In 2018, Rio Tinto opened the fourth and final kimberlite pipe for mining. Rather than deposit waste rock on a short haul dump and rehandling the waste to its final location as inert cover material at closure, the material is directly long hauled and placed in final form to meet closure criteria.

By implementing progressive closure, not only are net present costs reduced by over 10 per cent but final closure landforms are completed ahead of schedule, heavy mining equipment utilisation is increased, acid rock drainage risks are reduced and visual amenity is increased.

Diavik Diamond Mine

Key questions to ask about progressive closure

Has the business case for progressive closure been fully considered with site leadership, considering the full range of benefits?
Have all opportunities for progressive closure been explored?
Have the appropriate internal stakeholders been considered in the evaluation of progressive closure opportunities and risk, with the corresponding sign-off?
Have resources required for progressive closure been included in short- or medium-term plans (financial and physical resources)?
Is progressive closure aligned with and integrated into the LoM planning and closure planning?
Is progressive closure aligned with post-closure land uses?
Are lessons learned from progressive closure tracked and communicated? Are successes with progressive closure being communicated with external stakeholders?
Are there opportunities to involve external stakeholders with the design, implementation or monitoring of progressive closure works?
Are costs fully tracked and compared to estimates? Are learnings on the true costs of implementation incorporated into cost estimates?
Are as-builts being sufficiently documented to facilitate lessons learned and regulatory approval?
Are reductions in liability accurately identified and incorporated into closure cost estimates?
What incentives would be appropriate to encourage site leadership to apply resources to progressive closure activities?

Tool 5	Key messages for social transition
Tool 11	Social investment for closure

The term ‘social closure’ is more commonly used in the industry at present. However, it often has a negative connotation that can impede discussions with stakeholders. As such, ICMM suggests ‘social transition’ as a more appropriate term.

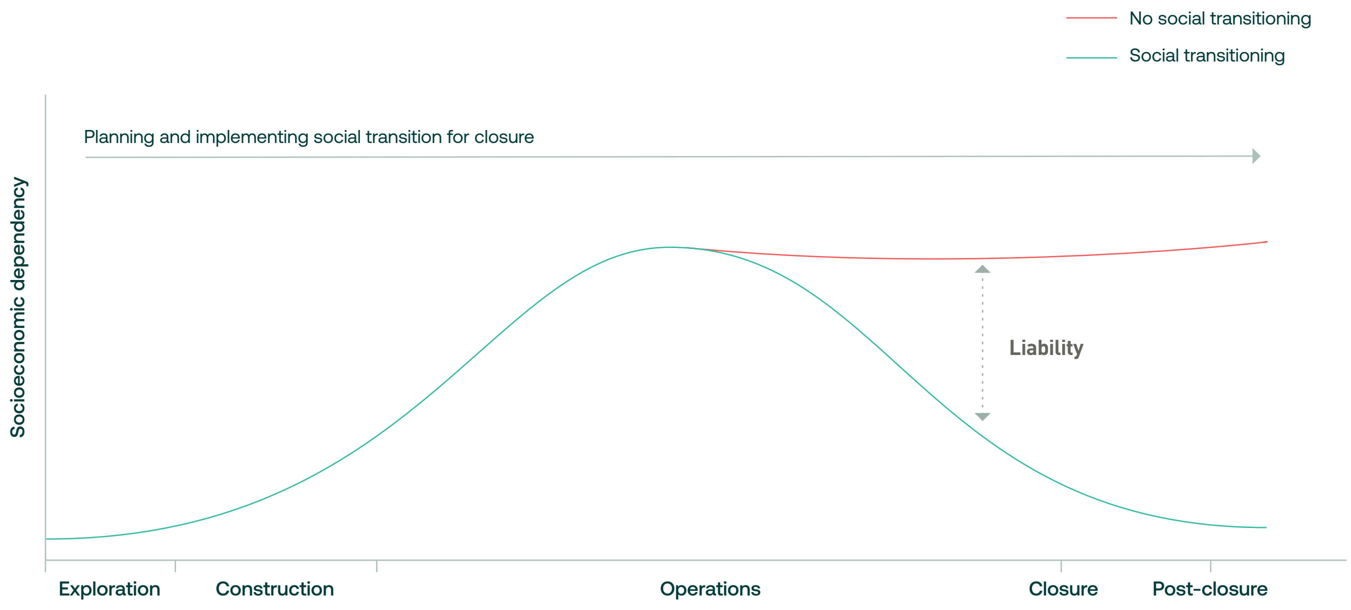
As with other closure management aspects, proactive planning and management for the social transition at closure is key for minimising negative impacts and capturing benefits. Host communities that have grown dependent on mining operations will experience considerable socioeconomic impacts at closure.

This can be especially true for those in remote areas or in developing countries where the mine may become the primary local economic driver and take on a de facto leadership role that would otherwise be the responsibility of government. Governments in these scenarios often have limited capacity or resources and, in some cases, share the same expectations as the communities.

Figure 7 illustrates the development of socioeconomic dependency on mining activities over the life of the operation. The figure illustrates the differing outcomes when social investment is strategically directed towards initiatives that foster economic diversification, and when no efforts are made towards facilitating the transition.

Good practice: Social transition for mine closure recognises risks associated with local dependence on the mine and consequently creates opportunities to encourage the development of sustainable post-closure options. The mine can build capacity of local communities and their governments to meet their needs without the mine’s involvement.

Figure 7: Social transition through the LoA (illustrative example)



It can be challenging to define boundaries of a mine's responsibility for socioeconomic development. However, experience shows that investment in social transition can result in sustainable and resilient community outcomes when government, community and other partners share in the decision-making, responsibility and process of closure.

Good practice: Social transition for mine closure that considers government-led development plans helps to reinforce the role of government and enable ownership by the local community over social investment programmes in the long term.

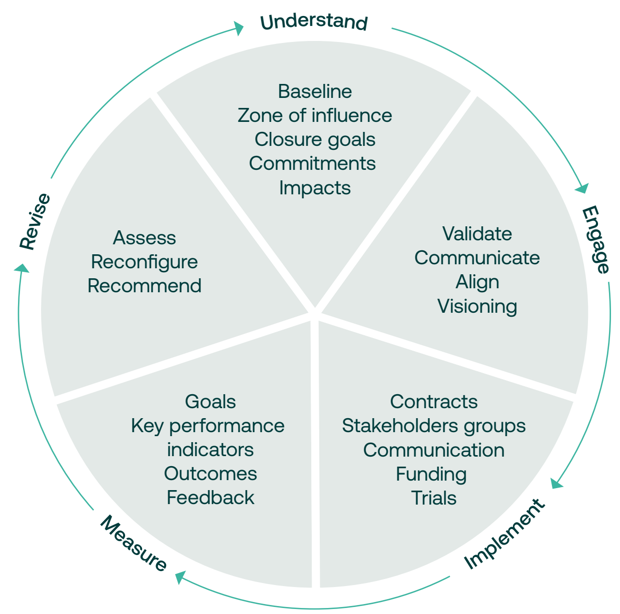
Planning for social transition to closure

Planning for social transition should be an integrated and iterative process involving multiple mine departments and stakeholders. This planning process is incorporated into the overarching mine closure plan, either through a dedicated social transition plan or through planning integrated into the mine's overall closure plan. The iterative nature of planning for social transition is similar to the iterative nature of closure planning as a whole.

Good practice: Social transition planning should integrate the identification of social risks and their mitigation measures into the earliest phases of mine planning. Incorporating the right specialists and stakeholders early in the selection of objectives can help ensure that the closure plan includes social transition objectives.

Figure 8 shows a five-step iterative process. In the context of planning for the social transition to closure, the initial 'understand' step links to the knowledge base and understanding the extent to which socioeconomic dependence on the mine has developed (or is projected to develop). In the 'engage' step, communication is undertaken to develop and validate the approach to social transition, while implementation may include actions from securing funding and undertaking trials to full implementation of programmes. In the 'measure' step, results are compared to the goals that were set for implementation. These results are then used in the iterative process to revise and update the approach.

Figure 8: Iterative Nature of Social Transition Planning and Management



The company's approach to social transitioning will require consideration and management of:

- how planned or unplanned developments such as mine expansion or construction of new infrastructure change the mine's zone of influence; this can result in changes to project stakeholders, and the nature of the mine's social and environmental setting.
- the operating life of surrounding mine operations and other industries.
- implications of local procurement policies during operations and subsequent impacts on suppliers post-closure.
- workforce recruitment and retrenchment planning.
- interest, availability and capacity of local community representatives in participating in the social transition planning process and the type of future leadership roles they can take on.
- the impact of generational changes over the LoA, and the resulting evolution of needs and desires in the community.
- communication of closure internally (employees) and externally (local communities, government, etc) – refer to Tool 5: Key messages for social transition.

Case Study

Economic diversification plan for Thompson, Manitoba, Canada (Vale)
Thompson, Manitoba has evolved as a diverse urban centre that functions as a regional service hub in Northern Manitoba, Canada. However, economic volatility, coupled with an announcement by Vale in 2010 that it was to close its smelter and refinery by 2015, prompted Vale to support economic diversification of the region. The Thompson Economic Diversification Working Group (TEDWG) was formed following extensive discussions that included the city and multiple stakeholders including indigenous rightsholders.

An agreement was adopted that identified specific funding in priority 'streams' to address infrastructure, economic development and other operational needs articulated by the TEDWG and city leadership. The TEDWG process represents a best practice in both procedural and technical capacity building to ensure local stakeholders can fully engage in planning for the long-term sustainability of their community. It also highlighted how practical tools, multi-stakeholder dialogue and planning can transform the challenges presented by mining transition and changing demographics into opportunities for sustainable growth.

Social investment for closure

Social investment for closure includes those aspects of social investment that focus on generating post-closure economic and social returns in local communities and on building community resilience to the impacts of mine closure. Refer to Tool 11: Social investment for closure and case study example on Vale's approach to economic diversification through strategic social investment for closure.

Basic principles for social investment in support of social transition for mine closure are:

- **Align** social investment around a shared vision of a post-mining future.
- **Focus social investment for closure on building resilience** – that is, building the long-term capacity of stakeholders to transition through the changes resulting from closure and to benefit from the presence of mining.
- **Start early** in developing social investment for closure and implement progressively throughout the LoA. This process cannot wait until closure is imminent.
- **Integrate and coordinate** social investment with other closure-related activities, both within the company and with other local stakeholders.

Stakeholder engagement at Yanacocha mine, Peru

- **Develop a strategic, planned and resourced approach** to social investment for closure.
- **Partner** with others to identify and prepare alternative long-term economic opportunities.

Social transition costs

Estimating the cost and effect of the social transition process for closure planning presents specific challenges. Unlike other elements of closure cost estimation, social transition costs do not typically have readily available, experience-based unit costs or easily measurable quantities. There is considerable variability among sites with respect to socioeconomic, environmental and political settings, stakeholder expectations, community capacity, etc.

Social transition costs can include factors such as:

- costs associated with updating the knowledge base.
  - social and health impact assessments.
  - community sensitivity analysis.
  - economic diversification studies.
- costs associated with operational or corporate aspects of the mine.
  - employee training or reskilling programmes.
  - staff and contractor redundancy costs.
  - partnership costs (advisory boards, fund management, etc).
  - communication and media planning and implementation.
- costs associated with implementation of social transition.
  - stakeholder engagement and grievance management.
  - social investment implementation.
  - relocation costs including planning and implementation, the latter of which may be significantly different from initial costs depending on how well migration, supply chain, etc have been managed during the LoA.
  - final land use and infrastructure costs to meet community or government vision and their requirements.
  - post-closure monitoring, measurement and reporting.

Much of the expenditure towards effective social transition should occur during operations, including projects that aim to support a sustainable local economy post-closure. At closure, social transition activities should ideally be well under way, with the community and key stakeholders already mobilised and implementing their community development plan, with limited need for ongoing support from mining companies.

It is important to ensure that there is a clear linkage between the social transition costs and the other components of the closure cost. If the social transition cost is not embedded in the overall closure cost estimate, there can be an incorrect accounting of true closure cost (see case study example on Anglo American's approach to social transition planning at Landau colliery).

Case Study

Social transition integration in planning at Landau colliery, South Africa (Anglo American)
Anglo American completed the scoping, development and implementation of a social transition plan for Landau colliery in Mpumalanga, South Africa during operations to reduce closure liabilities. The plan followed a well-defined process and project management approach to better define the scope. The work demonstrated that the following processes supported successful social transition planning:

- Integrate the social transition plan into the overall mine closure plan (social transition is seen as an operational activity).
- Review and update existing operational processes in line with the plan.
- Develop a detailed stakeholder engagement plan.
- Update and improve the current social transition plan by implementing the stakeholder engagement plan.
- Use the basis of estimate document and the risk assessment as living documents and operational tools to be updated, which will improve the social transition plan and estimate.
- Move from 'our plan' to 'their future'.

Anglo American incorporates social transition into their operations. As a corporation they have identified that improving operational activities will maximise the reduction of post-closure residual impacts and obtain the best value from allocated resources and funds.

Key questions to ask about managing social transition

Has the knowledge base been updated for social transition?
Has a socioeconomic impacts and opportunities assessment been undertaken to understand community capacity and opportunities for economic diversification? Have partnering opportunities been explored?
Has messaging around closure been integrated into the stakeholder engagement programme? Has it been included in the initial approval/permitting?
Has a social investment programme been developed with a focus on sustainable post-closure programmes and implemented during operations or as early as possible?
Are training programmes in place to facilitate upskilling employees for post-closure responsibilities and to improve their employability?
Has a retrenchment plan been developed with consideration of staggering reduction in workforce and assigning post-closure responsibilities where possible?

Closure Costs 012

Mining companies, regulators and investors share a common interest in ensuring the costs of implementing mine closure are accurately identified and clearly communicated. The estimation and reporting of costs present a unique set of challenges as closure costs may need to be estimated based on designs and assumptions made prior to construction of the mine, and then updated regularly over the LoA incorporating changing information.

These updates may occur over a span of years or even decades, prior to detailed design and implementation of closure construction stages at the end of the mine life.

This section provides an overview of the different types of cost estimates that may be needed to respond to the needs of mining companies, regulators, investors and other stakeholders, followed by a summary of recommended practices and considerations for developing all types of cost estimates.

Types of cost estimates

Several types of cost estimates are used to characterise the financial aspects of closure. It is important for mining companies to make clear distinctions between the different types of cost estimates as they serve different purposes. The basic types of closure cost estimates are outlined in Figure 9.

While much of the underlying source information for each of these estimates should be based on the most recent version of the mine closure plan, the numerical values are typically different as each responds to different user needs and will be prepared under different sets of frameworks. Understanding the differences and points in common for these types of estimates is key to the efficient use of information and to providing useful estimates. A brief overview of each type of estimate is provided in the following subsections. For further information refer to ICMM's *Financial concepts for mine closure (2019)*.

Figure 9: Closure Cost Estimate Types

LoA	Financial Liability	Sudden Closure	Regulatory Estimate Ffinancial Assurance)
Costs that the operator expects to incur in the context of the current mine plan at the end of the mine life	Estimated liability based on applicable accounting requirements	Cost to close the operation in its current state	Costs that form the basis of a guarantee provided to a regulatory body

Life of asset cost estimate

The LoA cost estimate responds to the internal planning needs of the mining company. While there are variations in how each company defines these estimates (and the terminology used), the estimates address the full expected closure-related costs that the company will incur for a site that operates through its full life and executes its planned mining activities to exhaust the mineral resources.

The LoA closure cost estimate includes the total cost of ownership expected to be incurred, including costs associated with all existing facilities and mining features, as well as all those facilities not yet constructed, land disturbances not yet incurred, mining not yet undertaken and progressive rehabilitation not yet undertaken that have been included within the LoM business plan. It also includes monitoring and maintenance costs over the anticipated post-closure period. This cost estimate should be carried in a mining company's cash flow model for planning and budgeting of capital and operational expenditures and ideally is fully integrated and presented in the mine business plan.

Other common characteristics of the LoA closure cost estimate are as follows:

— Owner costs (rather than third-party costs) are normally used where it is reasonable to assume that the owner would use its staff and equipment for executing the tasks. If the mine owner does not propose to execute the closure works using its staff and equipment, third-party costs should be used to estimate the cost.

Tumela mine, South Africa

— Credit for completed progressive closure can be incorporated directly into the estimate.

— The costs are normally calculated in accordance with the operational cost model.

— Salvage value may be considered where appropriate and internal business standards and guidelines permit. As salvage values are subject to wide variations, conservative valuations should be used, and should be supported by third-party quotes and evaluation.

Financial liability cost estimate

The financial liability closure cost estimate must be developed to comply with accounting obligations and reporting principles, usually the IFRS, or in the USA the GAAP. The amount is also known as an asset retirement obligation, closure provision or reclamation liability.

The following are key characteristics of a financial liability cost estimate:

— The cost estimate is based on the **present value** of future costs of the current disturbed footprint that will be incurred over time to retire the asset and meet legal, regulatory and agreed third-party (including stakeholders) commitments, considering the current disturbance. Constructive obligations and exclusions may vary in jurisdictions, but typically the financial liability cost estimate does not include:

  - closure and rehabilitation costs of future environmental disturbance or facilities yet to be installed/constructed and any personnel severance-related costs.
  - potential salvage value for equipment and infrastructure.

— The discount rate used for present value calculations is a pre-tax rate(s) that reflects current market assessments of the time value of money and the risks specific to the liability (except for risks reflected in the future cash flow estimates).

— The costs to be included in the estimate are those where environmental disturbance has occurred, or facilities that have been installed/constructed that require decommissioning and rehabilitation.

— Mine owner execution rates or third-party rates may be used/required as applicable for closure activities.

— Obligations that will be required after decommissioning should be included, including long-term water management, monitoring and maintenance, etc.

— The cost estimates are typically generated in partnership with a creditable independent third party that provides expertise in mine closure.

— The cost estimates must be acceptable to corporate financial auditors.

The amount considered in the financial reporting will need review at each reporting period to ensure that the value continues to reflect the mining company's obligations. As an element of financial reporting, this cost estimate is typically prepared under the direction of the company's executive management team and is subject to third-party auditing.

Sudden closure cost estimate

A sudden closure cost estimate is typically developed and used for internal planning purposes to aid in options analysis and decision-making. The estimated sudden closure cost would reflect all costs for immediately implementing closure, with no exclusions.

Costs that would form a part of the sudden closure cost estimate include closure works, workforce retrenchment costs, management, studies, and care and maintenance costs associated with deferring closure works. The cost estimate would also include post-closure costs such as those for maintenance and monitoring. Not all companies calculate this number and commonly use the financial liability number.

Regulatory cost estimate

In many, but not all, jurisdictions the regulator may require some form of financial assurance funds that will be available to complete closure works in the event the mining company goes bankrupt or otherwise abandons the site. This financial assurance is sometimes known as a guarantee or a closure bond. However, several other forms of acceptable financial assurance exist. Laws requiring financial assurance have arisen to address a history of abandoned sites in many jurisdictions.

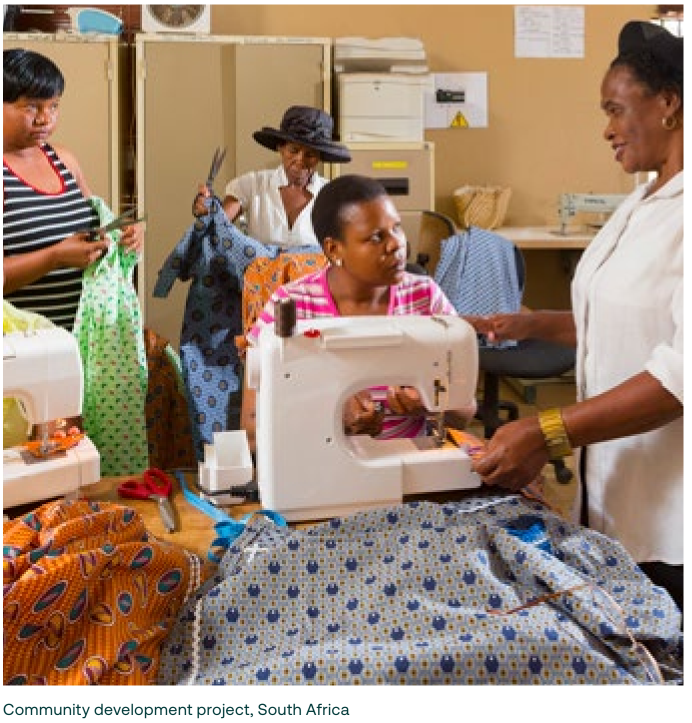
There is considerable variation among jurisdictions in how the financial assurance amount is estimated and administered. Typical characteristics include:

— The cost estimate is based on the closure activities presented in a closure plan that has received approval by the regulator.

— Cost estimates consider third-party costs, intended to be representative of the cost the government would incur to implement the closure plan if the mine was abandoned.

— The cost estimate may be based on the current disturbance, the disturbance planned within some set time limit or the currently approved extent of final disturbance.

— There is often a credit against the financial



Community development project, South Africa

Porcupine Dome mine, Canada

assurance for satisfactorily completed progressive closure works, to act as an incentive for progressive closure. Credit is typically not granted for progressive closure until the relevant authorities have officially accepted the work as complete and effective.

— Cost estimates usually must be updated on a set schedule, or when there are substantial changes to the mining operation.

— There may be a requirement for third-party audits or certification of the cost estimates made to establish the financial assurance.

— The cost estimate format may be specified by the regulator (ie there may be a standardised spreadsheet or other model used to present the costs).

— The rules relating to present value estimates vary greatly between jurisdictions. If discounting of future costs to present value is permitted, the discount rates may be specified by the regulator or subject to negotiation.

— Similar to financial reporting obligations, most jurisdictions with financial assurance requirements do not allow for potential salvage value for equipment and infrastructure to be included.

— Internal mining company costs, such as employee severance costs, taxes and financing costs, are not normally included in financial guarantees.

There is considerable variation in the forms of financial assurance accepted in different jurisdictions. Each type has advantages and disadvantages, and the range of feasible options should be considered carefully in terms of their financial implications for the mining company. Third-party guarantees, such as irrevocable/unconditional bank guarantees and insurance bonds, are relatively common, as are renewable letters of credit. Cash deposits, trust funds, collateral and insurance policies are also used, as are a variety of alternative options such as parent company guarantees, balance sheet tests and financial strength ratings.

Calculating closure costs

The estimation of closure costs is both challenging and of considerable importance to mining companies. Closure costs can have a material impact on a mine's book value and therefore need to be adequately accounted for at all phases of planning and execution. Further, in recent years, heightened attention and scrutiny has been placed on closure costs by company directors, shareholders, regulators and the general public, as these costs have often been underestimated. This has in turn placed more emphasis on the transparent communication of the closure cost estimation process.

This section provides an overview of the elements needed to develop closure cost estimates, including anticipated scope of the cost estimate, the information needed for its development and selecting the appropriate accuracy (or estimate class) for the conditions and closeness to closure of the site.

Scope

Cost estimates require a clearly defined scope. While some aspects of the scope will vary depending on what stage of the mine life the site is at and the final purpose of the cost estimate (as described in the preceding section), the following are the kinds of direct costs typically included in closure cost estimates:

— decommissioning and demolition of structures, and clean-up of contaminated sites.

— earthworks, including re-sloping, channel construction/expansion, placement of erosion protection material, relocating waste materials, cover construction and borrow source development.

— implementation of rehabilitation measures, including seeding, planting, fertiliser placement, maintenance and other related activities.

— water management, including surface and groundwater management.

— treatment of water, including water treatment plant construction and operation.

— liner installation or removal.

— construction of seals on underground mine openings to surface.

— post-closure monitoring and maintenance.

— access control and signage.

— disposal cost.

— costs of funding the management of future or long-term activities related to residual risks.

— closure planning and decommissioning investigations and studies to inform and assist in development of the closure designs.

Indirect costs and additional company costs that may not be addressed and included in all types of closure cost estimates include:

— mobilisation/demobilisation of contractors, consultants and other support services.

— retrenchment of staff.

— socioeconomic programmes.

— engineering, procurement and construction management (EPCM) costs.

— health and safety plans, construction monitoring and QA/QC.

— costs for management of closure activities, including management and supervision, power, water and sewage services, fuel and supplies.

— closure planning activities.

— interim care and maintenance costs (sometimes needed while closure designs are being finalised).

— ongoing dam safety inspections and reviews.

The above lists are not exhaustive, and not all the above activities will be applicable at all sites or are necessarily included in all types of estimates.

Information needs

A closure cost estimate will only be as good as the information used in its development. The quality and detail of the information used can be expected to increase as closure activities get closer to execution, either as part of ongoing investigations, research and studies, progressive closure or final closure. Some of the information will be provided in the closure plan while other aspects will require the input of the cost estimating team and from the mining company's closure management team.

The following types of information are needed to generate closure cost estimates:

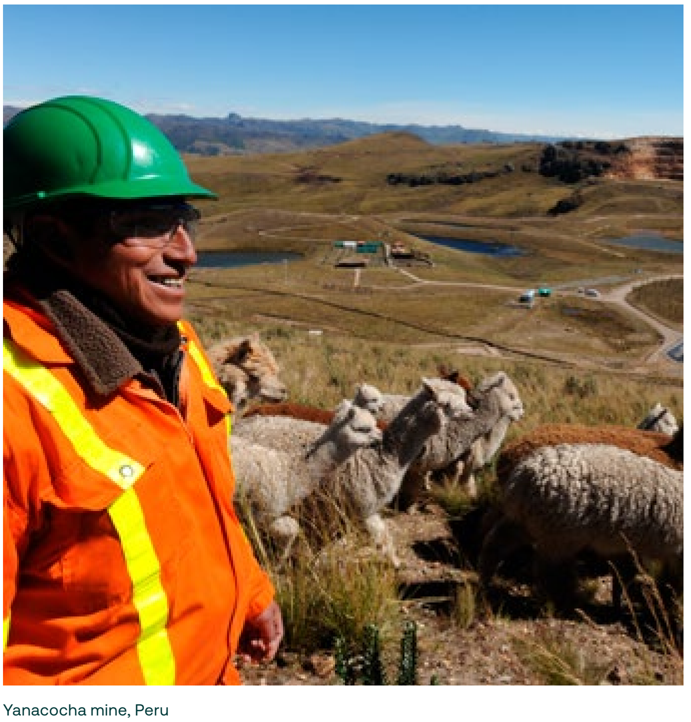
— a closure plan with clear descriptions of the type and scope of physical closure activities to be implemented; where multiple options are under consideration, there should be a clear indication of which option is to be taken as the base case for use in the cost estimate – assumptions around operating activities (such as progressive infill) should be clearly identified.

— established basis of design and engineering standards to be adopted.

— clear descriptions of the scope and duration of activities planned for facilitating social transition and workforce retrenchment.

— a register of the facilities and infrastructure to be closed, including (but not limited to) plants and processing facilities, camps, power, water, waste management and temporary infrastructure equipment – early in the LoA, this information may be indicative, but in the years prior to closure detailed registers will be needed with sufficient information on dimensions and types of material to support demolition estimates.

— unit quantities, areas and volumes of mining features and closure domains such as open pits, waste rock



Yanacocha mine, Peru

Eleonore mine, Canada

facilities, tailings storage facilities, water containment facilities and heap leach piles, including volumes of material that will need to be moved for activities such as re-sloping and capping.

— schedule of closure activities, including durations of planned or required monitoring and maintenance activities and the proposed closure execution strategy (EPCM, engineering, procurement and construction, owner or third party, etc).

— register of formal commitments with associated financial obligations not captured in the above, such as technical commitments made in approvals documentation.

— the third-party equipment and infrastructure required to support closure activities, recognising that some of this may not exist on-site at the time of closure, or may need to be replaced.

— unit rates for individual closure activities or supplies required – the unit rates used to be based on on-site or industry experience, government guidance (or requirements) and contractor quotations.

— financial planning variables such as exchange rates and the rate of inflation and the discount rates to be used for any present value calculations – for financial assurance estimates, specific rates may be established by the regulatory authority.

As indicated above, the closure schedule is an input to the cost estimate. Typically, closure costs need to be realistically distributed over the closure schedule for planning purposes and for present value calculations. Closure costs will typically be incurred over the following three periods:

— **During the LoM (progressive closure):** The duration of this period will depend on the LoM and the nature of the mining operation as some operations present more opportunities for progressive closure than others.

— **During the implementation of closure activities:** Typically, this will be a few years, although this can vary greatly not only with the size and complexity of the site but also with the closure implementation plan. There may be site-specific drivers to spread the closure activities of a site over a longer period.

— **During the post-closure period:** Monitoring and maintenance costs will occur over a duration that can vary from a few years to costs that will be ongoing for the foreseeable future. Regulators may set minimum monitoring and maintenance periods.

Estimate accuracy

One of the most important differences between closure cost estimates and other types of cost estimates in typical mining applications is that closure costs frequently need to be estimated for the implementation of closure activities many years or even decades in the future. In this context, it is important to be realistic about the achievable accuracy of cost estimates.

The risk of underestimated closure costs underlies any discussion of estimate accuracy. More detailed estimates are generally desired to reduce this risk. Cost estimates for capital investments typically progress through different estimate classes as designs progress towards maturity and the level of detail in the estimate increases. While terminology and definitions of estimate classes vary among organisations, AACE International (Association for the Advancement of Cost Engineering) defines five levels of cost estimate, from Class 5 to Class 1, with the highest accuracy expected for a Class 1 estimate.

The question often arises in closure cost estimating, what class of cost estimate is needed? When closure works are imminent, the answer is usually clear. Most mining companies have well-defined processes for evaluating and approving capital investments, with stage gates or similar decision points, and clarity on the timelines needed for approval. These procedures are generally applicable to imminent closure works. There is, however, one important difference between closure and other types of capital investments: with closure, 'do nothing' will not be an option for consideration.

At the very earliest stages of planning, prior to disturbance (and the associated financial reporting requirements) very high-level (often referred to as Order of Magnitude) cost estimates (Class 5 or similar) are generated. However, more detailed estimates (Class 4 or similar) may be more appropriate to screen alternative closure activities. With a greater level of detail in closure planning, especially for high-risk items such as water treatment, associated security, and general and administrative expenses, the overall mine design can be influenced to a greater degree and focus on reducing this type of long-term liability. Once disturbance occurs, financial reporting needs typically trigger a requirement for a greater level of accuracy, at least for the base case option. The closure plan revisions through the mining life cycle should incorporate the most recent alternative screening and cost estimate.

The progression over the LoA from Class 4 estimates to more precise costing is normally a decision for the closure management team and/or company policies and procedures that will require the weighing of various factors. Some of the factors that should be taken into consideration when evaluating the appropriate level of cost estimate are:

- regulatory requirements or expectations – regulators may request a higher level of estimate than might be chosen for mine planning needs.
- the LoM – mine lives of five years or less will immediately begin with a more precise estimate than mines with greater mine lives.
- the probability of significant changes in the mine plan.
- the probability of major changes in the preferred closure activities, particularly considering planned research, studies or design work.
- the probability of changes in the mine schedule.
- the cost of rework – more detailed cost estimates will be costlier to update or redo than less detailed ones.
- the availability of information to inform the cost estimate.
- the risk of a false sense of accuracy – when mine closure is distant, a very detailed estimate may convey an unrealistic sense of accuracy, given the changes in mine plan that can reasonably be expected.
- the risk of poorly informed decisions where insufficient data is available.

It is expected that closure costs will become more certain over the LoM as the project operations develop, knowledge is gained, designs and studies are advanced and site-specific experience with cost is developed. This experience would include experience gained through field trials and progressive closure.

For deterministic cost estimates, the value is expressed as a single point estimate. A contingency amount may be added to partially address the risk that costs are greater than the estimated value. Contingencies are usually calculated as a fixed percentage of the total direct and indirect costs, with the amount of the percentage reduced as the class of the cost estimate is increased. Contingencies are used to address additional costs that are not known at the time of making the estimate but that can be reasonably expected to occur based on experience. They do not address all risks, and in particular do not cover costs that could be incurred due to significant changes in scope or extraordinary events such as natural disasters. Regulatory authorities may require a contingency to be added to the amounts estimated for financial assurance. Contingencies are not required to be included on closure liabilities on the balance sheet.

As indicated in the previous section, the quality of a closure cost estimate (accuracy and completeness) is strongly influenced by the quality of the information used in developing the estimate. A probabilistic approach to cost estimating can be used to present transparently the confidence in each input to the cost estimate, and the impact of that confidence on the final estimated amount.

In the probabilistic method, a possible range and likelihood of costs for each activity is assigned and a statistical model is used to express the estimate as distribution of probable costs. The result of a probabilistic cost estimate is expressed as a combination of costs and probabilities, such as 'There is a 50% likelihood (P_{50}) the closure cost estimate will be up to or less than USD 85,000,000 (and 50% chance costs will exceed the estimate) and an 85% likelihood (P_{85}) the closure cost estimate will be up to or less than (and a 15% chance of exceeding) USD 117,000,000.' While this method provides considerable transparency, it can result in some difficulty in terms of identifying what is the correct value to use in reporting. The method is also more labour intensive to apply.

Key questions to ask about closure cost estimates

Are cost estimates built to a level of detail that is appropriate for the anticipated mine life remaining until closure and for regulatory requirements in the jurisdiction?
Is the closure cost estimate documented fully in a way that can be audited by a third party? Are changes auditable? Is the costing spreadsheet/database easily navigated? Can the integrity of the model be demonstrated?
Are assumptions realistic and defensible? Are there major data gaps preventing good assumptions?
Are all major assumptions fully documented? Do they require agreement from internal stakeholders? Have the assumptions been sourced from the right people?
Are cost estimates built from an up-to-date LoM plan and closure plan?
Have all potential costs required to close a mine been captured, including physical costs of implementing closure works, decommissioning, post-closure monitoring and maintenance, and site management/support through closure implementation and post-closure?
Have costs for implementing the planned social transition been included?
Is a uniform approach to closure cost estimation applied across the business, including a process for internal and external audits?
Are there up-to-date unit rates that are appropriate to the class of estimate, and the site/location?
Are discount rates and inflation rates used properly and validated internally, or (in the case of financial assurance) calculated in a way that is acceptable to the regulator?
Are contingency amounts appropriate for the estimate class or other requirements?
Do estimates account for risks, uncertainties and opportunities in successfully executing the planned work and achieving the desired outcomes?
Have the appropriate skills and expertise been involved in the development of the cost estimates?
Are adequate funding mechanisms being made available to meet closure obligations?
Is there a system in place to track actual versus projected costs, and incorporate learnings?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Closure Execution Plan

013

Tool 1	The domain model
Tool 12	Closure plan documentation

While the closure plan describes the actions that will be carried out as part of implementing site closure (see Tool 12: Closure plan documentation), a CEP identifies specific actions to be carried out during the LoA in support of closure planning and implementation of closure activities.

During the earlier stages of the LoA, it may be targeted towards closing gaps in the knowledge base, executing studies/research, refining closure objectives and criteria, integrating agreed aspects of the closure plan into the mine plan, carrying out progressive closure, conducting monitoring/inspections and reviewing the data collected. As the mine nears closure or as major progressive closure works are undertaken, the execution plan will evolve into a full implementation plan, with a detailed execution schedule.

During the mining life cycle, the CEP will have various elements, covering both the short term (the coming year or similar) and longer-range planning (up to the entire LoA). The plan may be addressed through one or more documents. CEPs will be dynamic internal planning documents, regularly updated or redeveloped over the mine life to reflect changing needs, changing conditions and new information.

The CEP should establish clear lines of authority and responsibility for implementing actions. The most detailed portion of the plan will address actions for the near term, with budget and staffing requirements identified. Actions might include:

— the required engineering, environmental or socioeconomic studies, trials, assessments and monitoring to fill key gaps in the knowledge base and ascertain closure risks and mitigation measures.

— the communication of the closure strategies/objectives so that key stakeholders are kept informed and engaged in the process.

— progressive closure opportunities/activities.

— review of monitoring and inspection data, with incorporation in the knowledge base of relevant learnings that will inform future closure planning.

— determining the point in time at which having a final executable closure plan is necessary.

Having a formal execution plan with clear responsibilities makes it far more likely that the above actions will be embedded in ongoing mine planning, with costs allocated and achievable scopes and timelines defined and regularly updated based on the outcomes of previous actions. Closure becomes part of what the mining operation does, embedded in the mine planning function.

Execution plans can be developed to address specific domains described in Tool 1: The domain model, such as applicable legislation, risk assessments, mitigation and post-closure land use for each domain.

Key questions to ask when developing the CEP

What is to be done to support closure planning in the short and long term?
For the tasks to be completed, when should they be started and finished?
What is the estimated cost to complete each action?
What other resources are required to complete the action?
Have risks been assessed based on current controls or future controls? In the risk assessment, has the maximum foreseeable loss been assessed?
Has a process for change management been identified?

Monitoring, Maintenance and Management

014

Tool 2	Monitoring, measurement and inspections

Following the completion of closure activities, monitoring (including measurement and inspections) is undertaken to document and evaluate the effectiveness of the closure activities at meeting agreed closure objectives and the success criteria. Monitoring is carried out with a focus on structures and facilities that remain post-closure, and on areas where there is an expectation or risk of impacts.

Where there is a pathway to relinquishment of the site, post-closure monitoring provides the information needed to demonstrate that success criteria are being met, or on a pathway to be met. See case study example on Glencore's Westside mine monitoring programme in confirming that success criteria have been met.

Monitoring could be conducted for various reasons to achieve different outcomes. Some of the most common needs include:

— Performance/success monitoring: to determine whether specific pre-set targets/criteria are being met/attained, typically the success with site success criteria.

— Information gathering monitoring: to obtain baseline information to populate/augment the closure knowledge base, typically to obtain data to a greater resolution to calibrate numerical groundwater model.

The focus of post-closure monitoring is primarily on performance/success monitoring and compliance monitoring. Refer to **Tool 2: Monitoring, measurement and inspections**, which provides an overview of typical needs for monitoring, measurement and inspections, to be considered when developing programmes for closure and post-closure monitoring.

At most sites, monitoring that is conducted before and during operations (including areas of progressive closure) will provide the experience and data needed to develop an appropriate and effective post-closure monitoring programme. Typically, the post-closure monitoring programme will be a version of the operational monitoring programmes, refined and optimised for post-closure. As such, it will integrate with existing baseline and operational monitoring data as well as traditional knowledge, where available, to place the post-closure data within a longer-term context. The refinement of operational monitoring programmes for post-closure may include the addition or removal of monitoring locations, changes in the frequency of measurement and reporting, and potentially adding or removing types of monitoring.

The required duration of post-closure monitoring is dependent on site-specific conditions (including regulatory requirements) and cannot be generalised. Post-closure monitoring programmes are often phased out over time, with the number of monitoring locations or frequency of monitoring events reduced as data is collected and trends documented. Some types of monitoring will be a one-time post-closure event, such as inspections to confirm that specific works have been carried out. In some cases, the post-closure characteristics of the site may require permanent or very long periods of ongoing monitoring. This is often the case for closure configurations that include large water-retaining dams, or active treatment of ARD/ML.

The development of post-closure monitoring programmes will involve input from regulators and other stakeholders, both on what is to be monitored and for how long. In jurisdictions with developed closure policies, post-closure monitoring plans will need to be approved by the corresponding authority, and results from the monitoring reported regularly.

Monitoring of sites against success criteria may lead to the identification of maintenance needs where success criteria are not met. Common maintenance activities include repairing or armouring areas of erosion, addressing areas where vegetation efforts have not been successful, and repairs or replacement of signage or access controls. Rehabilitated areas may also need to be managed as part of the broader ecosystem. This might include fire management through controlled burns, removal and control of weeds and control of illegal access onto the site.

Maintenance and management activities should be documented describing any ongoing activities, as well as providing any historical site information for the responsible party to which the closed site may be transferred as part of the relinquishment process.

Case Study

Westside demonstrates a well-planned and executed mine closure strategy (Glencore)
Rehabilitation of the Westside open cut coal mine near Lake Macquarie in New South Wales was completed in April 2012, just two months after mining operations ceased. It is managed by Oceanic Coal Australia Limited and is owned by Glencore.

The closure plan for the mine divided the site into a number of different rehabilitation domains with different completion criteria developed for each area and included a void that has been retained as a permanent lake.

Extensive surface preparation activities for rehabilitated areas commenced as soon as possible following the completion of mining activities. This followed a programme of progressive rehabilitation across the life of the mine.

Rigorous rehabilitation monitoring programmes have been in place at the Westside mine for many years. The Westside mine closure plan has been carefully implemented with a clear goal of achieving relinquishment in a staged manner, once sustainable vegetation has been established and agreed closure criteria have been met. Oceanic Coal Australia Limited has used sophisticated and innovative monitoring methods to ensure objectives are being met and have employed a proactive management approach to optimise ecological outcomes for the site.

The land has been successfully returned to high-quality native vegetation and is home to a diverse range of flora and fauna.

Recent monitoring found nine threatened species on the rehabilitated site, including grey-headed flying fox, masked owl, greater broad-nosed bat, little bent-wing bat, powerful owl, large-eared pied bat and squirrel glider.

Rehabilitated Westside open cut coal mine, Australia

Relinquishment

Relinquishment occurs when ownership, residual liabilities and responsibility for a former mine site can be returned to the corresponding jurisdiction or original owner, or transferred to a third party, following completion of closure activities and satisfying the agreed success criteria. If ongoing maintenance and management is required, the responsibility for this under relinquishment would also transition to the new responsible party.

Relinquishment may be either total, where the entire property is turned over to a third party, or partial, where parts of the property are turned over following completion of closure activities. Partial relinquishment may also be part of a progressive relinquishment plan, where the expectation is to achieve total relinquishment in a stepwise process.

Responsibly executed, relinquishment can be the final step in a successful mining life cycle. It marks the final transition of the site to its post-closure use, with the formal completion of a mining company's involvement. Relinquishment is not necessary for a successful mining life cycle, as in some instances the desired post-mining land use may be achieved without relinquishment.

The concept and practice of relinquishing a company's obligations on a closed mine is influenced by local laws as well as global and local community expectations. The clarity of a pathway to relinquishment varies widely between jurisdictions and may even vary between mines in a single jurisdiction.

While responsible relinquishment is in the interest of mining companies, and is widely desired, there are several impediments that should be understood if a realistic, effective pathway to relinquishment is to be developed. For the evaluation of relinquishment options, these challenges must be considered fully to maximise the chance of developing a closure plan that will set the site on a pathway to relinquishment. The business case for relinquishment must be balanced rationally, with the ongoing costs and liabilities of maintaining ownership of a site weighed against the cost and difficulty of securing relinquishment. Relinquishment may not always be the preferred outcome.

Pathway to relinquishment

The probability of achieving a successful relinquishment can be enhanced by adopting a pathway approach, with management, planning and communication throughout the mining life cycle designed to achieve relinquishment or improve the possibility of achieving it. Relinquishment plans and criteria may be developed over a long period of time. During this time, changes in government, changes in policies and shifting stakeholder opinions may all make relinquishment more (or less) difficult.

Good closure planning practice can help with setting a site on the pathway to relinquishment. Specific actions that will improve the possibility of relinquishment are as follows:

- Evaluate relinquishment options from the earliest stages of closure planning.
- In evaluating post-closure land use, consider the compatibility of land use options with relinquishment.
- Evaluate the legal structure in the jurisdiction and understand both the elements that could support relinquishment and possible impediments (ie laws that will prevent relinquishment).
- Involve regulators in discussions about relinquishment and understand their concerns.
- Monitor the state of practice and learnings from

Case Study

While there are challenges to achieving relinquishment, it has been attained in a number of jurisdictions. The following examples illustrate cases and locations where relinquishment has been attained. For the examples in the USA and Canada, it should be noted that even after relinquishment, the legal structure does not permit full relinquishment. If environmental impacts attributable to mining activities should be discovered after completion of the relinquishment, the mining company would remain liable.

USA (coal industry)
For coal mining in the USA, the path to relinquishment is clear, specific and highly regulated. Coal mining in the USA is governed under the federal Surface Mining Control and Reclamation Act of 1977, which lays out the pathway to relinquishment. While there is variation in the specifics of the application in different states, in general terms there is a financial assurance requirement. The financial assurance is released as rehabilitation is completed. After completion of rehabilitation activities and a set monitoring period (typically 5–10 years), a Phase 3 bond release is granted, and the mining company may sell the land, release it back to the original owner or otherwise release ownership, effectively relinquishing the land. If there is a need for ongoing activities, such as a water treatment plant, this can be addressed as a funded liability, with the liability for the treatment transferred to the third party.

Canada (Saskatchewan)
In Canada, mining is largely governed at a provincial or territorial level, although there are applicable federal regulations. Relinquishment has been undertaken in the province of Saskatchewan. The province developed the Institutional Control Program. Through this programme, mining companies can relinquish a site through a process that involves making deposits into separate funds that account for both the NPV of the ongoing monitoring and maintenance needs for the site, and a fund to address unexpected costs (residual risks). These funds are managed separately from the province's general revenues.

As of March 2017, six sites were under the management of the Institutional Control Program.

Australia (relinquishment processes)
Similar to Canada, the Australian mining industry is governed at a state or territory level with each jurisdiction having its own closure-specific obligations as part of the mine approvals process, which fall under overarching Commonwealth law principles. Most mining approvals and tenement conditions are framed in such a way that in theory, control of the mine site is returned to the state or territory, discharging the company from all future maintenance and monitoring obligations. General guidance on the mine closure process, including relinquishment, is described in the Leading Practice Sustainable Development Program for the Mining Industry,[2] which aims to identify issues and potential solutions for sustainable development of the Australian mining industry.

Over the past 25 years, however, 70 per cent of mines in Australia have undergone unplanned closures for various reasons, including economic, technical, regulatory, social and other unforeseen circumstances, leaving few examples of successful relinquishment.

2. Source: https://archive.industry.gov.au/resource/Programs/LPSD/Pages/LPSDhandbooks.aspx

successful relinquishment, especially in the jurisdiction under consideration.

— Engage with communities and stakeholders early on the topic of relinquishment and see if a pathway can be developed that is compatible with their needs and desires. If the end land use is desirable to them, look for opportunities to ensure that feedback reaches regulators.

— Look at the development of specific, measurable success criteria that are clear, with input and agreement from regulators and stakeholders.

— Look at partial or progressive relinquishment to demonstrate the concept and help regulators and stakeholders gain confidence.

— Identify and communicate residual risks clearly and openly. Discuss acceptable risk thresholds. Investigate a residual risk fund or similar mechanism to facilitate the acceptance and transfer of residual risk.

— Periodically re-evaluate and refine relinquishment options and the pathway to relinquishment, incorporating the knowledge gained throughout the mining life cycle.

— Track the business case for relinquishment and be prepared to abandon the concept if it does not make economic sense.

Key questions to ask about relinquishment

Is relinquishment a realistic endpoint for the mine site?
Is relinquishment an objective of the mine closure plan?
Are there SMART success criteria agreed with regulators and stakeholders?
Is there a community engagement strategy that addresses relinquishment?
Are the long-term monitoring requirements and the implications of those requirements understood?

Temporary or Sudden Closure 016

While the expectation is that mines will continue uninterrupted operation from start-up to the completion of the economic extraction of the ore, temporary or sudden closure of mines can occur. Both have implications for closure planning.

Temporary closure is a suspension of mining activities for a limited period. During temporary closure, the site is maintained. This is also called a 'care and maintenance phase'. In sudden closure, a mine goes into final closure ahead of the previously planned timeline.

Operations may go into temporary closure or sudden closure for a variety of reasons. Typical reasons include:

— financial pressures (market conditions).

— environmental incidents (floods, earthquakes, *force majeure*).

— social incidents (major health epidemics or civil action).

— regulatory authority actions or changes.

— structural failures (tailings storage facility failures, open pit slope failures).

During temporary closure, maintenance works are carried out in anticipation of the site returning to active production. Equipment and staff will remain on-site, with appropriate care taken of all site infrastructure, including ongoing monitoring of mine waste facilities and the environment. From a regulatory and closure planning point of view, many aspects of temporary closure should be indistinguishable from regular operations. All environmental controls will remain active, discharge limits will be unchanged and financial assurances will be maintained in place (or possibly even reduced if progressive closure works continue to be carried out during the care and maintenance phase).

A temporary closure may last for months or even years until the site returns to active production. On the other hand, temporary closure may be a precursor to final closure of the site (due to financial or regulatory considerations). For this reason, temporary closure often triggers regulatory scrutiny to confirm that financial assurances are adequate and that the mining company has appropriate plans and resources in place to implement final closure if needed. Depending on the jurisdiction and the cause of the temporary closure, updates to the closure plan and the financial assurance amount may be requested. The mining company may need to develop a detailed care and maintenance plan, documenting the work that will be done to keep the site in compliance with applicable regulations. The care and maintenance plan is outside of the scope of the closure plan, although some jurisdictions require a simplified care and maintenance plan to be included in the closure plan.

Sudden closure typically presents several challenges for implementation of the closure plan. These include:

- Closure designs may be at the conceptual or pre-feasibility stage and may need to be advanced on an accelerated schedule.
- The configurations of mine facilities may be different from the final configuration considered as a basis for closure designs. This may require rework, or major revisions to design concepts.
- Studies that were in progress to support closure may not be complete. The impact on closure designs of completing or not completing the designs will need to be considered.
- Schedules for the implementation of the closure plan will likely need to be re-evaluated and adjusted.
- Alternative contracting approaches, such as design-build, may need to be considered for some closure works.
- Engaging with the regulator will likely be necessary to ensure that necessary permissions are in place for the implementation of closure works. For works that respond to critical safety or environmental concerns, accelerated permissions are usually possible.
- Factors that led to the sudden closure may also affect the financial resources available for implementation of the closure works.
- Availability of third-party contractors to execute the proposed work may need to be considered.

At each stage of the mine life, it is good practice to have a contingency closure plan in place for sudden closure that identifies the key areas of the site closure plan that will require modification in the event of a sudden closure.

The socioeconomic impacts of both temporary and sudden closure are difficult to manage. Either can occur at a time when plans for facilitating social transition are not fully developed or implemented. By the nature of these closure events, there may be very little time to communicate with external stakeholders in advance. Either event is stressful for mine employees, contractors and suppliers.

The strategy for mitigating the socioeconomic impacts will vary greatly depending on the cause of the closure and on the socioeconomic setting. In all cases, clear communication is beneficial, and a communication strategy and engagement plan to keep stakeholders informed is important. It is good practice to have a high-level contingency plan in place to guide actions, and to keep the plan updated as the relation between the mine and the stakeholders evolves.

The social transition plan in the event of a sudden closure may be a modified version of the plan that was developed in the principal closure plan. Managing social transition in the case of a temporary closure will likely require a case-specific approach as one of the most important variables (the duration of the temporary closure) is unknown.

Key questions to ask about temporary or sudden closure

Has a risk assessment been conducted to determine which assets in the mining company's portfolio (as appropriate) are most at risk of sudden closure?
Is there a plan for sudden closure, appropriate to the current state of the mine development?
Is there a plan addressing care and maintenance needs for the site in the case of temporary closure, or high-level guidance for developing one?
Are there contingency plans in place for communications and engagement with stakeholders (including workers) in the case of either a temporary or sudden closure?
Is there a clear line of communication to ensure that the teams involved in closure planning are informed with the maximum possible anticipation of a temporary or sudden closure?
Is there appropriate security at the site to manage risks associated with theft, vandalism or unauthorised access?
How will regulatory expectations be managed and by whom?

Closure Governance

Effective planning and implementation of mine closure will involve resources from many disciplines across a mining company and directly affect its financial performance. As such, closure governance involves reconciling the roles and relationships of numerous stakeholders within the mining company (and joint venture partners and/or parent corporation, where applicable), as well as the goals of closure with the overall goals of the organisation. Corporate and closure governance will relate directly to the process of decision-making and the interactions between the stakeholders involved in solving the collective closure challenges.

All publicly listed mining companies are required to have clearly defined governance structures, with a board of directors that is responsible for corporate governance. The decision-making required in planning and implementing closure will take place at different levels throughout the corporate governance structure. Ideally, decisions will take place at levels that are commensurate with their impact and importance.

To ensure an adequate level of closure governance, it is recommended to establish the following:

— company policies or standards for closure to establish expectations, roles and responsibilities in a form that is compatible with corporate structure.

— a closure committee to coordinate the closure planning process and its integration into operational planning.

These are described in more detail in the following subsections.

Company closure standards

The establishment and implementation of company policies and/or standards that include closure is imperative for mining companies. Such standards provide a consistent approach to closure across operations, and fully implemented will maximise value through managing risks and opportunities.

Some of the topics that may be addressed in the standards include:

— documenting the approach to closure governance.

— defining site-specific closure obligations.

— specifying the approach to identifying, managing, reviewing and documenting closure-related risks and opportunities.

— identifying controls and standards for incorporating mine closure planning into the initial mine assessment process.

— defining expectations for incorporating closure requirements in business plans.

— defining the level of detail/accuracy required for closure plans and costs at each stage in the mine life.

- defining requirements for regular updates to closure plans throughout operations so that the plans reflect the current mine plan and the level of information available.
- outlining specifications on the contents of the closure plan:
  - these may differ from closure plan requirements as specified by the regulator.
  - where there are differences, these differences may be addressed by generating an 'internal' plan, or a version of the external plan that contains additional chapters to address corporate requirements.
- providing guidelines so that closure planning advances in a timely manner to the level of detail required – this is particularly important to avoid costly periods of care and maintenance after the end of operations while closure designs are being completed or approved.
- providing guidance on:
  - the integration of progressive closure during operations.
  - estimating closure costs for different final uses, including the differences in cost assumptions for financial reporting obligations (governed by applicable accounting practices), financial assurance (governed by jurisdictional regulations) and LoM planning (governed by internal corporate practices).
  - requirements for the frequency of updates to closure cost estimates.
  - these may need to be updated more often than the full closure plan due to needs for internal/external financial reporting or regulatory obligations.
  - requirements for stakeholder engagement as an integral part of closure planning.
- providing guidance on environmental, social and safety expectations.
- providing guidance for managing sudden or temporary closure.
- providing guidance on the pathway to relinquishment, including approaches to engagement with regulatory entities and stakeholders.

The company guidance may exist as a single document or across several related documents.

The company guidance may exist as a single document or across several related documents. Where a single comprehensive document is prepared to address closure, it is likely to have linkages to other corporate policies (such as those for project definition, sustainability and community relations). Those linkages should be explicitly identified in the closure guidance.

Good practice: Have a comprehensive mine closure standard that addresses the full range of corporate policies related to closure. This document will link with other corporate policy documents.

Closure committee

Establishing a closure committee for implementation at the asset level has emerged as best practice to confirm that the closure planning process is carried out in accordance with company standards and legal requirements, and that it is fully incorporated into operational planning.

The make-up and organisation of the closure committee will vary between companies and will be closely related to each company's overall approach to corporate governance, as well as the size and number of operations. The committee will typically be a site function, with support from a corporate level. The committee will typically be a site function, with support from a corporate level. Table 1 provides examples of key roles and responsibilities that may be identified for a closure committee. The role of the closure champion in this committee is critical, as the champion will be responsible for liaising with other key leaders within the organisation. The role should be implemented from the early stages of the mine life.

A RACI (responsible, accountable, consulted, informed) matrix should be developed by or with the closure committee to identify the key roles, including both the committee members and relevant stakeholders outside of the committee. In developing the RACI matrix, consideration should be given to stakeholders in corporate governance structures, including the board of directors, company management, executives, shareholders and employees. External stakeholders may also be included in the matrix. Establishing a RACI chart for external stakeholders is also helpful as it can assist to clarify accountabilities and is a useful insight into stakeholder perspective of their role in the closure activities.

While closure has historically been an environment function at many mine sites, making closure a planning function can help ensure that closure planning is appropriately incorporated into overall mine planning.

Change management

Management accountable for mine operations will change during the life of an operation. While there will be some unavoidable loss of knowledge and continuity with these changes, steps can be taken to minimise the loss of knowledge. Part of this will include succession planning so that for each role there are one or more defined successors in the organisation. Other steps that can help with change management are:

— providing documentation of trade-off studies and risk assessments conducted during the mine life.

— making sure that documentation identifies not only the reasons for the selection of chosen closure activities but also the reasons that other measures were not carried forward.

— monitoring data from operations and closure that should be managed in searchable data bases with various site staff familiar with their operation.

— keeping detailed records of all progressive closure, including areas closed, methodologies used and monitoring data; the records should include tracking of reclaimed areas in a geographic information system (GIS).

— preparing as-built drawings of all mine facilities and closure works.

In addition to the committee roles identified in Table 1, it may be useful to establish a stakeholder forum. This forum provides means for the operations to effectively consult with key stakeholders throughout the mining life cycle and develop joint strategies and plans for addressing closure-related issues. This forum would typically be championed by the committee lead for community liaison and development, with support from other committee members.

Table 1: Centralised closure committee roles and responsibilities

Role	Responsibilities	
Closure champion	— leads the development of the closure process — engages leadership throughout the organisation on closure planning, including corporate, management and operational leads — implements rigorous planning and project management processes so that the closure plan is incorporated into the LoM plan — ensures that closure plans are updated as circumstances change or as knowledge improves — makes sure that the closure cost estimate is updated and communicated	— ensures the CEP is implemented as per the specified timelines — facilitates a multidisciplinary collaboration of key mine personnel (such as mine planners, engineers, finance, corporate, and social and environmental teams) for the closure plan implementation — leads the implementation of the closure plan — leads regulatory engagement on the closure plan — monitors performance against agreed criteria — facilitates financial liability reporting
Community liaison and development	— facilitates and manages stakeholder input into the development of the closure plan — maintains consultation and communication with government, community, employees and other interested parties — leads local community engagements — leads or provides input to social investment programmes	— develops strategies and plans to minimise job losses and mitigate adverse effects on communities and the local economy — implements training programmes and social legacy projects — assesses and reports on the success and progress of all job loss and retrenchment management programmes planned and implemented — evaluates mechanisms for transfer of infrastructure to community
Human resources	— owns the workforce transition strategy	— develops strategies and plans to minimise job losses and mitigate adverse effects on workforce
Technical specialists – mine engineering, rehabilitation manager, geotechnical, water, etc (in-house or contractor/consultant)	— coordinates design and research studies where needed to address data gaps or key uncertainties — guides the implementation of appropriate closure activities	— leads progressive closure — provides or coordinates adequate training for community takeover of existing infrastructure (eg operation of boreholes/wellfields)
Finance/accounting	— ensures provision of funds for progressive and final closure execution	— reports liabilities in accordance with financial reporting standards
Operational leadership	— facilitates formation of committee	— approves/allocates resources

The following terms are defined for purposes of this document:

Acid rock drainage/metal leaching (ARD/ML): Acidic drainage from mine wastes resulting from the oxidation of sulphides such as pyrite and from contact with water. Often associated with metal leaching generating elevated concentrations of metals in the drainage. Metal leaching may also occur without acid conditions. Also known as acid mine drainage.

Closed mine: Mine at which all mining activities have ceased but in respect of which the owner, agent, manager or permittee remains responsible for compliance with regulations and the mine owner's obligations under the permit for the mine.

Closure activities: Definitive actions that will be carried out during implementation of the closure plan.

Closure domains: Domains comprising site features that have similar closure requirements. An asset can be divided into a number of physically or socially distinct domains.

Closure execution plan (CEP): The plan that identifies specific actions to be carried out during the mine life in support of closure planning and implementation of closure activities.

Closure objectives: A qualitative description of what is to be achieved through the implementation of the closure activities. The objectives are site specific and may be specific to individual mine domains, or aspects of closure. Closure objectives are derived from the overall closure vision and closure principles.

Closure principles: Common precepts that form the basis of and guide selected closure activities, such as physical and chemical stability.

Closure risk assessment: The closure risk assessment assesses the risks and opportunities associated specifically with closure and post-closure.

Closure vision: High-level description of what a company wants to achieve through implementation of the closure plan, which guides the overall closure strategy and selection of closure objectives.

Decommissioning: This is the process of taking infrastructure out of active service, which begins at the end of its utility for site activities and ends with the removal of all unwanted infrastructure and services.

Decontamination: Removal of contaminants from buildings or other infrastructure. May involve activities such as asbestos abatement, pipeline cleaning and general cleaning/washing. Often required as preparation for recycling or reuse of assets.

Demolition/deconstruction: This is the process of physically taking apart infrastructure and may involve disassembly of some or all of the structures, or destruction of infrastructure with heavy equipment or explosives.

Divestment: Process by which the company sells part or all of its assets. This can occur during any stage of a mining project, and entails a process of transfer of ownership, infrastructure, liabilities and closure responsibility.

Engagement: Interactions between people, often a company and its stakeholders. Can involve but not restricted to consultation, communication, education and public participation.

Financial assurance: Funds that will be available to complete closure works, even if the mining company goes bankrupt or otherwise abandons the site. This financial assurance is sometimes known as a guarantee or a closure bond. Required by government authorities in many jurisdictions.

Heap leach: Using chemicals to dissolve minerals or metals out of an ore spread out as a lined/impervious pad. The solution percolates through the crushed ore, leaching out the ore.

Knowledge base: The collection of site-specific information that will inform the closure plan, including physical, environmental, social and regulatory information. Initiated with baseline data and updated with additional information as it is collected.

Life of asset (LoA): The length of time an asset (including but not limited to mine, processing facilities, refineries, smelters, rail, port, utilities, towns and associated infrastructure) is owned, operated and closed by the mining company up until divestment or relinquishment. This LoA period includes exploration, development, operations, closure and post-closure.

Life of mine (LoM): The length of time a mine is, or is planned to be, in production. Based on a mine plan developed in consideration of the available capital and the ore reserves or a reasonable and justifiable extension of the reserve estimate.

Local community: Refers to communities that will be impacted directly and indirectly by the mine and will be most affected by closure.

Mine waste facilities: General term for installations designed and constructed for the storage of wastes generated by mining and processing activities, including tailings storage facilities, waste rock facilities, spent heap leach piles, slag heaps and process residues. Does not include domestic landfills or non-mining hazardous waste areas.

Mining life cycle: This is the full period of the mining process. Typically includes exploration, development, operations, closure and post-closure. Synonymous with the LoA.

Multiple accounts analysis: A multiple accounts analysis (also known as a multi-criteria analysis) establishes two or more 'accounts' that are weighted based on a qualitative and transparent assessment of their relative importance to the decision. Various options can then be rated on a numerical scale in each account, and a weighted total calculated for the option.

Net present value (NPV): The difference between the present value of cash inflows and the present value of cash outflows over a period, taking into account the time value of money, with future values discounted to the present day considering compound interest over the time period.

Partial relinquishment: Where part of the site is transferred to a third party, and the remaining area or areas remain the responsibility of the mining company. See also relinquishment.

Post-closure: General term referring to the period after the completion of all works needed to implement the closure of the site. Sometimes used to refer only to a period of monitoring and maintenance leading up to relinquishment but may include a period in which ongoing activity (such as the operation of a water treatment plant) is needed.

Post-closure land use: Refers to the use of mined lands after the completion of extractive mining and closure activities.

Post-closure maintenance and management: Includes activities required to maintain and manage infrastructure and rehabilitation until relinquishment is possible, or on an ongoing basis if not.

Post-closure monitoring: Includes monitoring after closure, including socioeconomic, water quality, water quantity, terrain, ecological and air quality monitoring. Results are compared to success criteria.

Post-mining land use: Refers to the use of mined lands once active mining is complete. This may include land use during the period when the site is undergoing closure activities, particularly when closure activities stretch over many years or decades (such as during water treatment). Differs from post-closure land use in that it includes land use that may occur before the completion of closure activities.

Progressive closure: A broad term that encompasses ongoing efforts throughout the mine operations that seek to advance closure activities during construction and operation. Examples of progressive closure activities include disturbed land rehabilitation and revegetation, decommissioning and demolition of unused infrastructure.

Progressive relinquishment: Relinquishment of a site in a stepwise fashion, typically over a number of years as discrete portions of the site are closed and brought to a condition suitable for relinquishment. See also relinquishment.

Reactive materials: Term used to refer to mine wastes that may change characteristics when exposed to air and/or water. Typically used to refer to tailings or waste rock that is susceptible to generating acid drainage when exposed to air and water but may be used for other material types.

Rehabilitation: The return of land to a stable productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounding land. Reinstatement of degrees of ecosystems and function where restoration is not the objective.

Relinquishment: The end of site ownership by the mining company and of their responsibility for the site, with transition of ownership and residual liability to the jurisdictional authority or a third party. Implies that the mining company has completed all obligations outlined in the closure plan to the satisfaction of the authorities (and possibly other stakeholders).

Repurposing: Beneficial reuse of a closed mining operation, whether through value-added reuse of the land (eg energy generation or residential), reuse of infrastructure at another site or derivative business opportunities to create positive economic activity.

Residual risk: The risk that a rehabilitated area (or closed mine), in the foreseeable future, fails to perform as predicted and the consequence of the failure will result in the need for repair, replacement or maintenance works, and thus associated costs.

Restoration: Re-establishment of ecosystem structure and function to an image of its prior near-natural state or replication of a desired reference ecosystem.

Revegetation: The introduction and establishment of new vegetation following land disturbance by seeding, planting or natural colonisation.

Social investment: Defined as the provision and use of company resources – in addition to those resources for core business activities and mitigation of negative impacts – to generate or enhance positive economic and social returns in local communities.

Social licence: The level of acceptance a population has for an operation, company or industry.

Social transition: The planning, considerations and activities undertaken throughout the LoA to develop and implement the transition of a community, including its workforce, towards closure of an operation.

Stakeholder: A person or group that is influenced by, or can influence, an operation.

Success criteria: Specifications/measurements/requirements that, if met, denote the success of the closure activities in meeting closure objectives. Success criteria may be numerical or narrative. They may have a time component and may also be linked to specific management or monitoring activities.

Sudden mine closure: Occurs when unexpected changes in conditions result in operations at the mine ending ahead of the date in the current mine plan.

Tailings storage facility: Area where tailings are stored. Typically, a permanent facility. Facilities may include dams or other structures to retain tailings. Also called tailings landforms, tailings impoundments, tailings management facilities and integrated tailings facilities.

Temporary mine closure: Mine closure where the site is secured and activities are carried out to reduce the potential of environmental impacts for the period of time before closure operations occur or mine reopens.

Waste characterisation: This is the process by which the composition of different waste streams is analysed.

Waste rock facility: Mine waste or spoil materials disposal areas, specific to mineral waste, not landfill or 'non-mineral' waste. Also known as waste dumps, waste piles, waste rock dumps, waste residue dumps. Overburden piles are where low-grade stockpiles remain at closure – these are often treated effectively as waste rock facilities.

Zone of influence: Represents the geographic area within which firstly, direct socioeconomic impacts can be attributable to a mining operation, inclusive of its activities (and those of its contractors), facilities, labour-sending areas and procurement of goods and services; and secondly, indirect impacts, including those on ecosystem services or where secondary or knock-on economic impacts are experienced.

Tools

Tool 1: The Domain Model

This tool provides a set of templates to be used when developing a plan for each of the domains.

A useful approach to dividing up the closure plan is to segregate the mine into specific areas or domains. Each domain is treated as a separate detailed entity within an overall plan that deals with common issues like drainage and site monitoring.

The following factors should be considered when developing a plan for each domain:

- the amount and area of disturbance
- applicable legislation
- hazardous areas and risk assessments
- a plan for deconstruction and decommissioning
- contamination and mitigation
- post-closure land use
- required earthworks and capping
- control of erosion
- a rehabilitation plan
- monitoring
- cost estimates
- research.

Escondida mine open pit, Chile

Each domain should have its own plan (see template provided). Assumptions, inclusions and exclusions should be documented throughout the operational life.

Examples of domains at a mine are:

— **mine voids**
  - open pits
  - underground mines

— **mine waste facilities**
  - tailings storage facilities
  - waste rock facilities
  - spent heap leach piles
  - slag and process residue

— **infrastructure**
  - buildings
  - roads
  - pipelines, powerlines
  - fuel storage facilities
  - water management infrastructure (including process and raw water facilities).

While the domain approach will not be optimal for all sites, it is often useful. In some cases, sub-areas within a given domain may require a different treatment, depending on interactions with other domains.

For accuracy, the operation should use GIS digital terrain models and aerial photos to illustrate the domain features and boundaries; 3-D models of voids and mine waste facilities are also useful.

XX Area	
Description	
Area of disturbance	Void xx hectares; waste rock facilities xx hectares
Status	Active
Closure date	xx void and waste rock facilities will be closed in 20xx
Infrastructure to be retained	Final void

Obligations Relating to Closure		
Subject	**Obligation**	**Relationship to closure**
Regulatory condition – rehabilitation	Progressive rehabilitation must commence when areas become available within the operational land	Incorporating details and requirements for leaving voids safe and stable after closure
xx	xx	xx
Final land use objectives	**Void** (a) Safe with minimal risk to the public, native fauna and livestock (b) Conceptual land use options include water bodies or partially filled water bodies. A decision will be based on the results of detailed geochemical and hydrological studies	
Examples	**Waste rock facility** (a) Provide an acceptable post-disturbance land use capability/suitability (b) Provide acceptable, stable post-disturbance landforms (c) Protect surface and groundwater quality on-site when leaving the mining lease (d) Close using technically effective and cost-effective methods and proven engineering practices to ensure that no long-term maintenance is required beyond the post-closure phase of five years (e) Make the area safe with minimal risk to the public, native fauna and livestock	
	xx	xx

Closure Completion Criteria

Description	xx void	Area (ha)	xx	Photo no	Photo xx	Timing	20xx–xx

Closure activities

(a) Excavate and haul waste rock material to construct perimeter bund walls

(b) Fencing of void perimeters

(c) Purchase and erect warning signs

(d) Final pit water balance and groundwater models

(e) Geotechnical stability assessment for long-term pit wall stability

Statutory sign-off

No	Yes	Date	Document reference no
√		xx	xx

Description	xx waste facilities	Area (ha)	xx	Photo no	Photo xx	Timing	20xx–xx

Closure activities

(a) Selective handling of acidic rock on outer waste rock facility face of xx facility – dispose of on top surface

(b) Re-profile xx stockpile to drain towards final void

(c) Re-profile central waste rock facility to drain towards final void

(d) xx stockpile – stable, minor leaching, no activities

(e) Excavate, load and haul inert oxide waste to the reshaped xx facilities

(f) Moderate earthworks to place store-and-release cover system (inert oxide rock) over potential acid-generating rock, reshape facility surface and revegetate

(g) Re-profile and deep rip the balance of the waste rock facility surface

(h) Minor erosion control works and seeding on the balance of the waste rock facility surface

(i) Geotechnical assessment to demonstrate long-term stability of facility

Statutory sign-off

No	Yes	Date	Document reference no
√		xx	xx

Post-closure activities Examples	**Void** (a) Continue surface and groundwater quality monitoring until a stable state is achieved, including void water qualities and monitoring void water levels **Waste rock facilities** Monitoring and maintenance of: (a) Revegetation works (b) Soil erosion and soil erosion control structures (c) Weed control in and around the rehabilitation area (d) Surface water quality in leachate collection ponds as per current monitoring schedules

Specific closure assumptions **Examples**	**Void** (a) The void will not be backfilled (b) The void will be allowed to flood naturally (c) Bunding and fencing will occur at closure (d) There will be no impact on groundwater as a result of water accumulating in the final void (e) The closure strategy adopted for this closure plan will be accepted by all stakeholders **Waste rock facilities** (a) Geochemical test work of the waste rock facilities will confirm the applicability of proposed closure methods
Closure material sources **Examples**	**Void** (a) 4,500 m3 of inert waste rock to construct 2 m high perimeter bund walls (b) 2,500 m of fencing (c) 50 warning signs **Waste rock facilities** (a) Selective handling machinery for acidic outer facility waste rock face (b) 80,000 m3 of inert waste rock from xx facility (c) Seed and fertiliser to rehabilitate 28 ha
Waste disposal sites	Not applicable
Other issues	None identified

Rehabilitation Costs ($)	
Engineering and rehabilitation cost	$500,000
Closure administration cost	$20,000
Post-closure management cost	$10,000
Total	$530,000
Costs not included	Consultant investigations on additional geochemical test work
Cost-saving opportunities	(a) There may be an opportunity to generate additional cash flow by processing the stockpile at the same time as reducing existing liabilities that would otherwise require re-profiling and rehabilitation (b) Reduce existing liability by aiming to gain sign-off of the xx waste rock facility and final void as soon as regulators finalise the progressive rehabilitation policy
Further investigations/ studies required	Long-term water quality and groundwater impacts will be needed, as well as investigations on geotechnical stability of the outer dump face and verification of cover depth to restrict infiltration, before regulators accept the final landforms as they are
Liabilities/risks/hazards	(a) The encapsulation method may not be effective in reducing acid leachate generation to acceptable levels (b) 'Hot spots' of potentially ARD/ML material may develop as acidic rock is exposed during any waste rock re-profiling

Tool 2: Monitoring, Measurement and Inspections

This tool provides an overview of the typical needs for monitoring, measurement and inspections, to be considered when developing programmes for closure and post-closure monitoring.

Water monitoring at Barro Alto, Brazil

There are numerous ways to organise the types of monitoring that may be carried out post-closure. For the purposes of this tool, the following categories have been defined:

— socioeconomic

— water

— terrain

— ecological

— air quality.

A brief overview of the typical components of monitoring for consideration for each of these categories is provided below.

Socioeconomic monitoring

Socioeconomic conditions will need to be monitored following closure, for both former workforce and communities transitioning to a post-closure economy. This monitoring is required in part because social investment programmes targeted at post-closure socioeconomic opportunities can take time to establish, become sustainable and reach an acceptable level of residual risk.

The indicators used in socioeconomic monitoring should consider indicators agreed upon through community visioning or regional planning processes. They should also consider the mining company's internal objectives and targets set for social transition.

Example monitoring indicators can include:

— income generation and financial well-being
  - earnings by individual/household compared to pre-operation, during operations and post-closure
  - proportion of households in affected communities generating alternative incomes

— economic diversification
  - proportion of households in affected communities participating in alternative livelihoods
  - employment rate of former employees and suppliers

  - proportion of businesses operating post-closure
  - proportion of new businesses
- post-closure land use/rehabilitation attainment
  - proportion of lost land restored to a productive capacity
  - changes in yield or productivity of crops
- social investment programme performance
  - proportion of social investment programmes continuing post-closure, disaggregated by community and by programme, as well as by gender and age where applicable
  - local migration trend
- traditional harvest economy metrics
  - land available for hunting, fishing and trapping
  - productivity measures for hunting, fishing, trapping and traditional food/medicine plant sources.

Methods for monitoring and evaluation in closure and post-closure typically involve social monitoring tools that were used during operations, adjusted as needed to reflect needs and capacities in closure and post-closure. Methods can include stakeholder perception surveys, household surveys, community consultation meetings and analysis of trends in community grievances.

Socioeconomic monitoring may be carried out by the mining company. However, given the lowered presence of company representatives at the mine site post-closure, and to bolster ownership by the local community of the social transition, monitoring can be undertaken by one or a combination of:

- **Government:** Involving government can help to ensure a monitoring programme is consistent with development plans and that monitoring results are considered in future planning decisions.
- **NGOs:** Organisations active in the local area often have existing relationships with the local communities; understand the local socioeconomic issues, needs and capacity; and may have ongoing community development programmes that meet the company's social investment and social transition objectives and programmes.
- **Community members:** Involving community members in the monitoring process would require capacity building and training during the operations or pre-closure phase to facilitate their participation in social transition monitoring activities. In some cases, it may be appropriate for company employees who are also resident in the local community to participate in the ongoing measurement and reporting requirements. However, this would need to be considered on a case-by-case basis to ensure the monitoring and reporting process remains transparent.

The nature and duration of the socioeconomic monitoring period post-closure should be established through collaboration with regulators and stakeholders. These should be the same parties that were involved in developing social investment programmes.

Socioeconomic monitoring will generate results to be compared with the project's socioeconomic baseline data. This baseline must include data that characterises the socioeconomic conditions while the mine is at full production and the supply chain has been fully established. If possible, the data set should also include the pre-mining baseline conditions.

Water monitoring

Water monitoring in closure can be divided into measurements related to quantity and quality.

Quantity-related measurements include both measurements of flow rates and levels. Common approaches for flow rate measurements include:

- flow meters on discharge pipes
- pumping records (including estimates based on pump characteristics and operating time)
- discharge weirs (with either manual or automated measurement of water levels over the weir)
- changes in water level over time from impounds of known characteristics (using stage-volume curves)
- estimates based on stream velocity measurements, cross-section characteristics and water elevation
- visual estimates based on visible flows
- information inferred from hydrogeological data (eg aquifer transmissivity and gradient calculations for groundwater well level monitoring)
- information inferred from water balance calculations – rainfall monitoring at a representative weather station is standard practice to inform water balances in operations and closure.

Water levels may need to be monitored for geotechnical purposes, erosion considerations or water use considerations, or to provide data for flow estimates. It is good practice to tie all water level measurements back to a common reference elevation. A common elevation reference point is usually established prior to the start of operations and should be maintained as the basis for measurements through closure and post-closure. This facilitates the comparison of measurements over a long period of time.

Groundwater levels are typically monitored with standpipe piezometers or vibrating wire piezometers. Standpipe piezometers have the advantage of permitting sampling of the groundwater for water quality measurements, while vibrating wire piezometers facilitate remote data collection using telemetry.

Surface water levels can be measured through different techniques. Traditional survey methods provide reliable, accurate measurements of surface water level, as do manual readings of calibrated surface water level gauges. There are also approaches available for remote measurements, including automated pressure transducers and radar measurement of water elevation.

Water quality measurements include those taken on both surface and groundwater samples. The methods for the correct collection of water samples, their handling and transportation, and analysis protocols are well codified.

Water quality monitoring programmes for closure typically include a range of parameters that have been selected based on the contaminants of concern specific to the mining operations.

Terrain monitoring

Monitoring of the terrain includes monitoring that is usually carried out to evaluate the physical stability of the site, with visual inspections, surveys, instrumentation, soils analysis and remote sensing.

Visual inspections: These are typically conducted by a qualified professional or designated person to identify signs of instability and erosion. For dams that retain water and tailings, this will include a regular site visit by a geotechnical engineer who will check the dam signs of instability such as slumps, cracks, seeps and erosion features. Other areas that are commonly inspected for some years following closure include dump slopes, covers, pit walls and other geotechnical structures. Large dams that retain water and tailings will typically need regular inspections on an ongoing basis (with additional inspections after extreme rainfall or seismic events), while other inspections may have the possibility of being phased out as ongoing stability is demonstrated.

Surveys: Surveys are used regularly in post-closure to supplement visual inspections. Surveys may be conducted to evaluate settlement (particularly of dam crests) or quantify other types of movement of the ground surface.

Instrumentation: Geotechnical instrumentation, such as slope indicators, lasers, extensometers and settlement plates, may be used to quantify ground movement. Where frozen ground conditions are important for ground stability or other aspects of closure, thermistor strings are used to provide measurements of ground temperature.

Soils analysis: Laboratory and field analysis of soil quality may be required during the implementation of closure works and in the post-closure period. This includes soil monitoring that is linked to the assessment of rehabilitation success, with measurements of parameters such as available nutrients, salt content, organics content and changes over time in bulk density or texture class. Soil monitoring may also be carried out for the assessment of soil contamination. During operations or the closure period, this may be done to evaluate if soil contamination is present, and then to confirm the success of remedial efforts. If there is a mechanism or suspected mechanism for recontamination of the soil, then there may be a requirement for ongoing resampling and analysis over a set period. As with water quality monitoring, soil sample collection and analysis methods are fully standardised (see, for example, the applicable ASTM standards).

Remote sensing: Remote sensing, with satellite, drone or aircraft-based sensor technology is used in a variety of fields to collect information. In mining applications, the use of Lidar technology to collect ground information is well established. Technologies are available that allow for the characterisation of a wide variety of ground characteristics that may be useful in closure applications, from changes in vegetation to evaporation characteristics.

Ecological monitoring

Ecological monitoring includes a wide range of activities designed to monitor the conditions of organisms living on the closed mine site following the completed closure activities. Ecological monitoring can be organised into the monitoring of terrestrial and aquatic flora and fauna.

These programmes typically share the need to develop formal field sampling plans and QA/QC procedures.

- **Terrestrial flora:** often undertaken to monitor the progression of revegetation with tracking of changing of vegetation density and distribution of species diversity.
- **Terrestrial fauna and avifauna:** most commonly undertaken to monitor the recovery of biodiversity in an area following the completion of closure works.
- **Aquatic flora:** typically undertaken to evaluate the impact of closure works and mine water discharges on aquatic vegetation.
- **Aquatic fauna:** often undertaken to evaluate the impact of mine water discharges to a receiving environment.

Ecological monitoring programmes generally focus on evaluating one or more of the following parameters:

- **Species populations:** evaluating the abundance and diversity of species in a given area. A common example would be measures of plant cover on a reclaimed area.
- **Biodiversity:** characterisation of the different types of species in a given area, including identification of invasive species.
- **Chemical uptake:** evaluating the concentrations of contaminants of concern in one or more species.

  A common area of concern is the uptake of contaminants in the plants used for revegetation, and subsequent bioaccumulation of those contaminants in animals or humans.

Ecological monitoring will generally be referenced to baseline data and/or data from reference sites.

Air quality monitoring

Post-closure monitoring can include monitoring for air quality, which may include ambient air quality and dust monitoring. Such programmes are almost always based on an extension of monitoring programmes in place to address air quality concerns during operations and closure. Dust generation is likely to continue through closure activities such as demolition and rehabilitation.

The completion of closure almost always results in a dramatic reduction or elimination of many potential sources of impacts to air quality, such as blasting, truck traffic and processing.

Post-closure air quality concerns typically relate to dust generation from tailings storage facilities or other areas of fine-grained deposits. As the technologies for the control of dust generation post-closure are typically robust and effective, it is usually possible to demonstrate improvements in air quality rapidly after completion of closure and limit the duration of the post-closure air quality monitoring.

Ecological monitoring at Boddington Gold mine, Australia

Rehabilitation monitoring at Tanami Mine, Australia

Tool 3: Objective Setting

The following worksheet tool can be used to identify aspects of the mine that may need associated objectives.

Site-specific objectives will be set for mining installations such as pits, infrastructure and mine waste deposits and may be derived from the mine's licence to operate, compliance conditions, risk assessments and technical designs.

Site-specific objectives can also be set for a variety of physical and social components of the site. The provided worksheet is also intended to prompt identification of potentially appropriate objectives. Not all aspects will be applicable at all sites.

Aspect	What must be protected?	What can be enhanced?	Objectives
Geology and soils			
Land use			
Surface-water hydrology			
Groundwater/hydrogeology			
Biodiversity			
Air quality			
Settlement status			
Transport networks			
Population and demographics			
Household composition, density and distribution			
Languages			
Culture and heritage			
Community groups and organisations			
Indigenous Peoples			
Livelihood and income streams			
Surrounding land uses			
Per capita income			
Economic context			

Aspect	What must be protected?	What can be enhanced?	Objectives
Artisanal mining			
Educational facilities and levels			
Health facilities and statistics			
Community infrastructure			
Government planning schemes			

Examples of objectives that might result from this exercise are:

Examples of general closure objectives	Examples of specific closure objectives with measurable success criteria
Land suitable for grazing	Land able to sustain grazing for nine months of the year (non-winter) for up to 100 head of cattle
Two small and medium-sized enterprises	Two small and medium-sized enterprises with total employment of 100 full-time equivalent local staff
Permanent healthcare facilities in village	30-bed (1% of population) permanent healthcare facilities with outpatient facility and maternity unit
Water supply to village	Reticulated potable water to a minimum of six standpipes in the village, with sustainable supply at 45 litres per person per day for the population of the village
Improvement in primary education	Achievement of greater than 70% attendance to Grade 4, with equivalent demographic representation of boys and girls

Where possible, the partial achievement of objectives should be set as milestones, as the following examples illustrate, so that there is a progressive means of assessing whether the operation is 'on track' to meet the defined closure objectives. The following table provides examples of milestones on the pathway to completion of the objective:

Closure activity	Milestone – 0%	Milestone – 25%	Milestone – 50%	Milestone – 75%	Closure objective
Rehabilitation	Final land use plan formulated	100 hectares graded, topsoil applied and seeded	200 hectares graded, topsoil applied and seeded	300 hectares graded, topsoil applied and seeded	400 hectares graded, topsoil applied and seeded
Capacity building	Determine current and future skill base in village, including gender equality	Vocational training programmes in place and full enrolment achieved	Transfer of vocational training administration to government-owned corporation	Self-funded, self-administered vocational training institution running at full enrolment	Future skill base achieved
Tailings dam closure	Tailings storage facility location and dimensions scoped	Capping options determined, and testing programmes commenced	Capping option chosen and material selection confirmed	Capping instituted on 50% of the (completed) cells in the tailings storage facility and under validation testing	Capping completed, monitoring in place

Objectives will be developed and refined over time. Brainstorming sessions may be appropriate for identifying objectives or testing the completeness of existing lists of objectives.

The following tables provide some suggested categories for objective setting (the left-hand column) and some words to act as prompts (the right-hand column) that can be used to formulate specific and quantifiable objectives to assist in closure planning.

The first table is to support setting objectives for social transition, and the second for objectives oriented towards environmental protection.

In both cases the list is not exhaustive, and elements should be added or deleted to suit the local conditions of the operation being considered.

This format of the tables lends itself to facilitated workshops in multi-stakeholder forums and helps identify social risks and opportunities in closure planning.

Objective setting for social transition

Closure category	Typical open question	Prompts
Poverty	What social and socioeconomic values or gains can be achieved in poverty reduction?	Quantity, quality, availability, potential yield, productivity, historical, modern, cultural, recreational, tourism, amenity, subsistence, agriculture, cash crop, stability, shelter, longevity, drought, flood, famine, health, contamination, positive legacy, negative legacy, utility, proximity, adaptability, stability, resource value appreciation, resource value depreciation, safety, character, unique, benchmark, respiratory, carcinogenic, replenishment, depletion, insufficient, excess, low, high, minimum, maximum, educational, future value, future cost, past value, past cost, improve, worsen, develop, destroy, add, remove, increase, reduce, popular, unpopular, repute, disrepute, ethical, unethical, government, NGO, policy, standard, guideline, practice, throttle, block, bottleneck, controlled, uncontrolled, stability, variability, instability, success, failure, catastrophic, chronic, modulated, peaky, predictable, unpredictable, proactive, reactive, indigenous, wealth, poverty, education, illiteracy, health, disease, trauma, capital, revenue, funding, operating capital, wages, salaries, income, GDP, GNP, markets, distribution channel, subsidy, partnerships, equity, investment, finance, lending, interest, collateral, profit, loss, asset, liability, enterprise, business, service, supply, goods, labour, exchange, trading, economy, rights, expectations, responsibility, accountability, governance, life expectancy, quality of life, leisure, demography
Hunger	What social and socioeconomic values or gains can be achieved in hunger reduction?	
Education	What social and socioeconomic values or gains can be achieved in education?	
Gender equality	What social and socioeconomic values or gains can be achieved in gender equality?	
Child mortality	What social and socioeconomic values or gains can be achieved in child mortality?	
Maternal health	What social and socioeconomic values or gains can be achieved in maternal health?	
HIV/AIDS, malaria and other diseases	What social and socioeconomic values or gains can be achieved in the management of HIV/AIDS, malaria and other diseases?	
Healthcare	What social and socioeconomic values or gains can be achieved in healthcare management?	
Water supply	What social and socioeconomic values or gains can be achieved in water supply?	
Employment	What social and socioeconomic values or gains can be achieved in the employment market?	
Youth employment	What social and socioeconomic values or gains can be achieved in youth employment?	
Employability	What social and socioeconomic values or gains can be achieved in the employability of people in the community?	
Technology	What social and socioeconomic values or gains can be achieved in the application of technology?	
Recreation	What social and socioeconomic values or gains can be achieved in recreation?	
Infrastructure	What social and socioeconomic values or gains can be achieved through the adaptation of infrastructure?	
Indigenous	What social and socioeconomic values, gains or losses are inherent to indigenous affairs?	

Objective setting for social transition		
Closure category	**Typical open question**	**Prompts**
Cultural	What social and socioeconomic values, gains or losses are inherent to the cultural heritage of the community?	
Enterprise	What social and socioeconomic values or gains can be achieved through the generation of enterprise?	

Objective setting for environmental protection		
Closure category	**Typical open question**	**Prompts**
Land resources	What environmental values, gains or losses are inherent to land resources?	Quantity, quality, availability, potential yield, productivity, scarification, sterilisation, species, biodiversity, habitat, historical, modern, cultural, recreational, tourism, amenity, grazing, subsistence, agriculture, cash crop, stability, shelter, longevity, drought, flood, famine, health, contamination, positive legacy, negative legacy, utility, proximity, adaptability, stability, resource value appreciation, resource value depreciation, safety, character, unique, benchmark, pH, metals, toxic, hazardous, respiratory, carcinogenic, velocity, volume, rate of flow, density, concentration, diffusion, dispersion, replenishment, depletion, insufficient, excess, low, high, minimum, maximum, educational, future value, future cost, past value, past cost, improve, worsen, develop, destroy, add, remove, increase, reduce, popular, unpopular, repute, disrepute, ethical, unethical, government, NGO, policy, standard, guideline, practice, throttle, block, bottleneck, controlled, uncontrolled, stability, variability, instability, success, failure, catastrophic, chronic, modulated, peaky, predictable, unpredictable, proactive, reactive, repopulation, extinction, indigenous, dominant, passive, feral
Water resources	What environmental values, gains or losses are inherent to water resources?	
Terrestrial flora	What environmental values, gains or losses are inherent to terrestrial flora?	
Terrestrial fauna	What environmental values, gains or losses are inherent to terrestrial fauna?	
Aquatic flora	What environmental values, gains or losses are inherent to aquatic flora?	
Aquatic fauna	What environmental values, gains or losses are inherent to aquatic fauna?	
Acid rock drainage	What environmental values, gains or losses are inherent to acid rock drainage?	
Air	What environmental values, gains or losses are inherent to air?	
Noise	What environmental values, gains or losses are inherent to noise?	
Waste	What environmental values, gains or losses are inherent to waste?	
Tailings storage facility	What environmental values, gains or losses are inherent to the tailings storage facility?	
Overburden dump	What environmental values, gains or losses are inherent to the overburden dumps?	
Final pit void	What environmental values, gains or losses are inherent to the final pit voids?	
Underground workings	What environmental values, gains or losses are inherent to the underground workings?	
Heap leach pad	What environmental values, gains or losses are inherent to the heap leach pad?	
Bore field	What environmental values, gains or losses are inherent to the bore field?	

Objective setting for environmental protection		
Closure category	Typical open question	Prompts
River diversion	What environmental values, gains or losses are inherent to the river diversion?	
Sewage treatment plant	What environmental values, gains or losses are inherent to the sewage treatment plant?	
Water treatment plant	What environmental values, gains or losses are inherent to the water treatment plant?	
Contractor accommodation	What environmental values, gains or losses are inherent to the contractor accommodation complex?	
Mine buildings and village	What environmental values, gains or losses are inherent to the mine buildings and village?	

Tool 4: Screening Alternatives for Repurposing

This tool provides a set of proposed steps towards identifying possible alternatives for repurposing sites.

At some closed sites, repurposing of the site is possible post-closure. Repurposing typically involves finding a new use for the site, either in whole or in part, that takes advantage of the site characteristics to provide a productive economic activity post-closure, or other beneficial post-closure land use.

There is a growing body of successful repurposing case histories in the mining industry, with examples of post-closure uses that range from power generation to tourist attractions. With a productive use of the land secured, repurposing facilitates the relinquishment of the former mine site.

Evaluating repurposing alternatives requires thinking broadly about possible options. This tool provides ideas to help identify and evaluate alternatives that may be feasible for repurposing.

The evaluation process outlined in this tool is to:

- ensure that the required information to start evaluating options is available
- look at the site characteristics that typically constrain or facilitate repurposing
- identify potentially feasible options.

Not all closed sites will be amenable to repurposing. In some instances, only certain domains may be available for repurposing. If the screening identifies an alternative land use and a positive business case can be developed, this approach may be incorporated into the mine closure plan. Prior to incorporation in the plan, the repurposing must be the subject of engagement with stakeholders to ensure the option aligns with what the community and government desires.

Step 1. Information collection	
Prior to screening alternatives for repurposing, the following basic information should be available from closure planning and post-closure land use option analysis:	
— population density – proximity to potential users — socioeconomic context — identification of indigenous communities — characterisation of environmental impacts — legal considerations/problems (landownership) — maturity/capability of future operator — status of landscape rehabilitation, including stability of slopes — soil, surface water and groundwater contamination	— status of decommissioning and infrastructure removal — buildings available for reuse — ancillary properties/buildings/infrastructure — local business partnering opportunities — water rights — neighbouring site issues — 'sacrifice zones' – areas that cannot be used — regional and local plans — potential offset requirements.

Step 2. Constraining and facilitating characteristics	
External infrastructure aspects to consider as part of the screening process could include:	
— industrial context — rail access to site — availability of high-pressure natural gas — access to electric transmission lines — available power options, including alternative/renewable energy supplies — availability of city/town sewer and water — access to major roadways	— access to airports — tourism potential — renewable energy potential — deep-water port/dock facilities — proximity to other 'compatible' industries — proximity to communities — land zoning/tenure.
Internal infrastructure, permit and utility considerations could include:	
— location and availability of reclaimed land and domains — existing water storage — available buildings for reuse, sale, lease; condition of buildings and maintenance needs — site utilities (power, water wells) — site transport (roads, rail) – extent, coverage, condition — remaining mineral resources for industrial purposes (eg rock, stone, sand, gravel)	— existing water abstraction and discharge permits (storm, industrial, effluent) — existing air quality permits — existing waste treatment or waste disposal permits — land contamination and feasible remediation levels (eg industrial, agricultural or residential levels).

<table>
<tr><th colspan="2">Step 3. Potential options to consider</th></tr>
<tr><td colspan="2">Residential and industrial options and considerations could include:</td></tr>
<tr><td>— regional planning, such as future residential growth area
— mixed use and industrial land use plans – light or heavy industry growth area</td><td>— other infrastructure or buildings, and available subsidies for economic development
— water and wastewater supply and treatment for community or municipality.
— Tourism potential and studies available</td></tr>
<tr><td colspan="2">Some of the non-industrial, non-residential options for repurposing to evaluate include:</td></tr>
<tr><td>— forestry, agriculture, rangeland
— solid (and hazardous) waste management (storage, transport, disposal)
— low-level radiological waste storage
— communications infrastructure
— deep-water port</td><td>— mining or metallurgy research and development
— water supply for agricultural and/or farming purposes (eg fish farming, livestock watering, crop irrigation)
— credit trading and offsets (compensation for rehabilitated site producing rich biodiversity)
— carbon sequestration.</td></tr>
<tr><td colspan="2">Power generation options should be evaluated, especially where the site is already connected to the regional power grid. State/federal/provincial incentives for renewable energy sources may apply and provide additional business-case enablers. Some of the options available include:</td></tr>
<tr><td>— solar farm projects (now successfully implemented at many sites)
— wind farms (also common)</td><td>— small-scale hydroelectric systems (in-line elevation drop)
— waste to energy, biofuels and other renewables.</td></tr>
</table>

Tool 5: Key Messages for Social Transition

This tool provides a collection of example key messages that are appropriate for each stage of the mining life cycle leading up to the implementation of final closure.

Communication and engagement with stakeholders will be an important part of planning for the successful social transition through the closure process. The example messages are provided both for communications with internal stakeholders and external stakeholders.

Phase: Design and permitting	
Internal — We are launching a process called 'social transition for mine closure' that will help us make strategic decisions during the mine planning and operations phases to support the well-being of local community's post-closure. — The process is being launched now to ensure decisions made early will support the objectives of the social transition; the process will continue until the post-closure phase of the mining life cycle. — This process will be led by our [social team] and will include cross-functional internal input and external stakeholder input.	**External** – messages included during environmental and social impact assessment (ESIA) consultation, as required according to local jurisdiction and company policy — Every mining project has a finite lifespan and every mining project will eventually come to an end. **To be communicated to internal and external stakeholders at all stages of LoM**. — Mine closure is an inevitable part of the mining life cycle, but it does not need to be the end of the social and economic growth of the local community. **To be communicated to internal and external stakeholders at all stages of LoM**. — We are currently looking at what decisions we can make and what programmes we can support that will help the community when this mine transitions from operations to closure. — We are interested in the thoughts and ideas you have about the future land use of this site.

Phase: Construction	
Internal — We are working with relevant business units to develop strategies for social investment, local employment, workforce training and local procurement that align with the social transition objectives. — We are engaging regularly with external stakeholders to ensure the social transition process reflects their own vision and priorities for a post-mining community.	**External** — We are seeking your input as we develop ideas to optimise opportunities for local employment, workforce training and local procurement to support the community's long-term sustainability. — We are working with [local communities] to help them [articulate/update] their vision for the community post-mining; this will help to ensure we are all working towards the same objectives during operations. — We [are/will be] seeking input from you to develop a social investment strategy that will ensure the programmes we support help build skills and capacity in the local community and enable continued economic growth post-closure.

Phase: Operations	
Internal — Progressive rehabilitation. — We are currently working to ensure our social investment, local employment, workforce training and local procurement programmes are contributing to the future social transition at closure. — Our shared social transition vision is [xx] and agreed objectives are [xx]. — We are working with community leaders to develop agreements for the transfer of buildings and infrastructure post-closure so they will be available for public use. — We are developing a social transition monitoring plan that will continue to track the changes and growth of the local community post-closure.	**External** — We are currently monitoring our social investment, local employment, workforce training and local procurement programmes to ensure they are effectively contributing to community outcomes. — We are in the process of developing agreements for the transfer of buildings and infrastructure post-closure so they will be available for public use. — We are developing a monitoring plan that will support you in tracking social and economic changes following mine closure. — We are seeking your involvement in a multi-stakeholder community development group to lead this effort. — The LoM could potentially change due to a number of factors – that is, commodity price, identification of resources, etc.

Phase: Pre-closure and closure	
Internal — As we prepare for mine closure, we are monitoring the implementation of our exit strategies related to local employment, workforce training and local procurement; the transfer of sites and infrastructure to the local community/government as per our signed agreements; and the transfer of ownership over all our social investment programmes to the local community/government. — We will be working with [local/regional] government to ensure the effective launch of the social transition monitoring programme, which they will lead to track social and economic changes in the community post-closure.	**External** — Thank you for all your work in helping design a social transition plan for this community. — As we prepare for mine closure, we are monitoring the implementation of all the commitments we have made to date, including: - completion of training programmes for workers not required during the closure phase - support for small business still actively contributing to our local supply chain - the transfer of sites and infrastructure to the local community/government as per our signed agreements - the transfer of ownership over all our social investment programmes to the local community/government. — We will soon be launching the social transition monitoring programme with the [local/regional] government, which will help the local community track social and economic changes following mine closure.

Tool 6: Social Transition Activities Checklist

This tool provides a checklist of activities that will assist planning for social transition from the early stages of design and permitting through to closure.

Planning for social transition should take place from the early stages of the mining life cycle. Although activities have been presented according to development phase, the checklist is intended to be applicable to greenfield projects, existing active operations and those that have been reopened/reactivated.

Activity	Resources	Stakeholders	Check
Phase: Design and permitting			
Conduct a desktop review of internal plans, policies and commitments related to the social transition for mine closure	Documents related to closure, mine planning and design, stakeholder engagement, social investment, local employment, workforce training, local procurement, socioeconomic baseline data	Environment team, mine planning and design team, operations management, social team, human resources team, procurement team, legal team	
Conduct a desktop review of external plans, processes or studies relevant to the social transition for mine closure	Regulatory requirements for mine closure, government plans/policies for local/regional economic growth, development, land use	Regulator, government, NGOs, academia	
Assess suitability of socioeconomic baseline data from ESIA for social transition planning purposes; plan to include social transition indicators in the next iteration of socioeconomic baseline update	ESIA	Environment team, social team	
Assess suitability of social impact assessment from ESIA for social transition planning purposes and plan for update during construction	ESIA	Environment team, social team	
Conduct a stakeholder mapping process to identify relevant internal and external stakeholders	ICMM's Community Development Toolkit	Social team, human resources team, community, government, NGOs	
Engage relevant internal stakeholders on social transition for mine closure; set internal objectives and procedure for internal collaboration going forward		Social team, environment team, human resources team, mine planning and design team, operations management	
Engage relevant internal stakeholders on mine planning and design to encourage alignment with social transition objectives	Mine design plan, mine business plan, risk assessments	Mine planning and design team, environment team, social team	

Activity	Resources	Stakeholders	Check
Engage relevant internal stakeholders on local employment, workforce training and local procurement to encourage alignment of construction phase strategy with social transition objectives		Human resources team, procurement team, social team, legal team	
Where appropriate, engage with external stakeholders on future land use and success criteria relevant to social transition	Mine design plan, mine business plan, closure plan, regulatory requirements for mine closure, government plans/policies for local/ regional economic growth, development, land use	Mine planning and design team, environment team, social team	
Phase: Construction			
Consider setting up social transition team to foster cross-functional collaboration on items that affect social transition for mine closure	Mine design plan, mine closure plan	Social team, mine planning and design team	
Transition team to track social transition plan objectives into development/update of mine closure plan; update social transition objectives and costs as closure constraints become more apparent		Social team	
Support the development of local employment, workforce training and local procurement strategies		Human resources team, procurement team, social team	
Support engagement with external stakeholders and commence discussions on leveraging socioeconomic benefits and current/ future land use discussions and business development; develop plan for longer-term facilitation of closure discussions	ICMM's Tool 11: Social investment for closure	Community, government, NGOs, academia, social team, industry peers, other private sector actors	
Engage internal and external stakeholders to develop a high-level social investment strategy that aligns with the local community's baseline socioeconomic context; incorporate handover of programmes/ infrastructure to local community/ government post-closure into closure plan	ICMM's Tool 11: Social investment for closure	Social team, community, government, NGOs	
External stakeholder engagement and implementation of social investment strategy	ICMM's Tool 11: Social investment for closure	Social team, community, government, NGOs	
Review socioeconomic baseline and impact assessment in line with current external and internal context	Mine design plan, mine closure plan ESIA and permits	Social team	

Activity	Resources	Stakeholders	Check
Phase: Operations			
Hold regular meetings of cross-functional group to foster cross-functional input on issues that affect the social transition for mine closure		Social team	
Ensure cross-functional input is incorporated into update of mine closure plan	Mine design plan, mine closure plan	Social team	
Launch and monitor implementation of social investment strategy	ICMM's Tool 11: Social investment for closure	Social team, community, government, NGOs	
Monitor alignment of local employment, workforce training and local procurement strategy with social transition objectives; support development of exit strategy for pre-closure and closure phases		Social team, human resources team, procurement team, government, community	
Review socioeconomic baseline and social impact assessment; update based on current external (and internal) context; review against management measures and social investment programme	ICMM's Tool 11: Social investment for closure Mine closure plan	Social team	
Draft and sign agreements for transfer of buildings and infrastructure to local community/government/landholders post-closure		Social team, government, community, legal team	
Provide training and capacity building to assist with sustainable community operation of transferred infrastructure		Social team, government, community	
Incorporate social transition monitoring into post-closure monitoring plan for the mine, or develop a standalone plan for monitoring social transition post-closure		Social team, government, community	
Phase: Pre-closure and closure			
Monitor implementation of exit strategy for local employment, workforce training and local procurement		Social team, human resources team, government, community	
Initiate transfer of buildings and infrastructure to local community/government		Mine closure team, social team, government, community	
Initiate handover of social investment programmes to local community/government		Social team, government, community, NGOs	
Set up key performance indicators and independent monitoring programme, grievance mechanism and communications method for implementation		Mine closure team, social team, government, community, NGOs	

Tool 7: Climate Change and Mine Closure Concerns

This tool provides a list of concerns that should be considered as part of the closure planning process, suggested management approaches to address these and suggested resources/tools to use in consideration of climate change in the closure planning process.

Mine voids and mine waste deposits are generally permanent modifications of the land, and their closure requires design horizons that extend for many hundreds of years. Closure planning should consider the impacts of a changing climate on closure design. Climate is an important input to closure design, and significant changes in global climate are predicted based on current climate models made.

Climate change is also a subject of regulatory and public concern. Questions around the impact of climate change on the closure plan and how it is being addressed should be expected in any review process. Several jurisdictions now have explicit regulatory requirements to address climate change in closure plans.

Concerns

Climate change can affect many aspects of closure design. Conditions may become wetter than historically observed or subject to more extreme storm events. Higher temperatures and drier conditions can also affect the water balance or ice conditions.

A few of the more common concerns that are regularly discussed are listed below:

— **Design storm changes:** Recent experience suggests that changes to rainfall intensity and frequency will affect statistically predicted design storm events. Whereas published historical records based on observations of a previous period may suggest a certain magnitude of event corresponds to a 1-in-100-year probability of occurrence, the future probability may be much higher once recent observed changes to the historical record and projected changes have been considered. This can result in much more robust designs being needed for hydraulic structures and for erosion control.

— **Water balance changes:** Drier or wetter conditions can affect the water balance, affecting the designs of closure activities such as covers and revegetation. Wetter conditions may overwhelm the storage capacity of store-and-release covers, resulting in greater infiltration. Alternatively, drier conditions may make it difficult to maintain water covers or saturated soil covers or reduce water availability for plants. Drier conditions could also result in benefits, with reduced volumes of water for treatment.

- **Baseflow conditions:** Drier conditions may result in reduced baseflow in streams or other receiving waters, resulting in less assimilative capacity.
- **Fires:** Increased frequency or severity of forest or grassland fires may negatively impact rehabilitation efforts or result in disruptions to site access/power.
- **Permafrost changes:** Many northern sites rely on permafrost conditions either to provide physical stability or to isolate wastes. Increases in the active layer of permafrost may negatively impact stability.

Management approaches

Some mining companies address climate change through a risk framework and conceptual modelling (eg groundwater, solute transport, etc). Probabilities of climate change and their effects are assessed together with other risk factors, and appropriate mitigations are adopted based on risk level.

In more general terms, management approaches can be divided into adapting or reacting to climate change.

Adapting to climate change: In this approach, the outputs from numerical models are used to project future climate at the site under a variety of scenarios. These projections are used to inform design. This may be in the form of modified design approaches or changes in risk profiles. The numerical techniques used, referred to as general circulation models or GCMs, are based on future scenarios outlined in the Fifth Assessment Report (AR5) produced by the Intergovernmental Panel on Climate Change (IPCC).[3] The AR5 outlines four possible climate change futures that represent different levels of future greenhouse gas emissions. Using the outputs from the available models to design for future conditions may reduce the probability of a significant failure in the design. However, the outputs from the available models may not be of sufficient detail or may have uncertainty that does not cover all the issues that may need to be considered, and there are limitations in the confidence in the predictions. There is also not a clearly accepted standard of practice for selecting which climate change scenario should be used in closure design; therefore, this work may have to be repeated at some time in the future.

Reacting to climate change: In a reactive approach, closure activities are designed based on our current knowledge. For example, water management structures could be designed to accommodate a 1-in-1,000-year flood or a probable maximum precipitation event, estimated based on data collected to date. If significant changes in climate occur in the future that invalidate or modify design assumptions, designs may be updated or the risk of not updating them evaluated. If climate change results in damage to structures, these will be repaired as part of ongoing maintenance. The reactive approach requires that there are resources available to assess, repair and modify closure structures as required. The reactive approach will tend to be more inexpensive in the short run as it will generally result in postponing capital expenditures and will reduce the risk of overdesign based on uncertain predictions. It may, however, be significantly more expensive in the long run if the future changes result in a failure of the design and significant repair/rework. This approach will also result in greater future risks, including reputational risks.

While both approaches are seen in practice, incorporating adaption to climate change in design and risk evaluations is now standard practice. It is also the only approach that could be considered compatible with closure scenarios without ongoing management of the site (relinquishment or 'walk away').

3. IPCC (2014). *Climate change 2014: synthesis report. Contribution of working groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [core writing team, RK Pachauri and LA Meyer (eds)]. Geneva, Switzerland: IPCC. 151 pp.

Resources

There are several resources available to help with consideration of climate change. As mentioned, climate change can be addressed as a risk and managed within the context of a risk-assessment framework (see **Tool 8: Risk/opportunity assessment and management**).

- ICMM's 2019 report *Adapting to a Changing Climate: Building Resilience in the Mining and Metals Industry* provides an overview of how a changing climate can impact the metals and mining sector, with a focus on measures to enhance and address climate resilience.
- More detailed downscaled climate projections may be available for the region or location of interest than available in the ICMM tool through climate data portals and watershed analyses from national, subnational and research agencies. The detailed downscaled climate projections could be compared to the output from the screening tool to better understand the differences between the current and projected climate data sets and understand the uncertainties that can influence design.
- The Mine Environment Neutral Drainage 2011 report *Climate change and acid rock drainage – risks for the Canadian mining sector*[4] provides information specific to the impact of climate change on mine closure activities.

4. Source: http://mend-nedem.org/wp-content/uploads/2013/01/1.61.7.pdf

Tool 8: Risk/Opportunity Assessment and Management

Risk management standard, Council of Standards Australia and Council of Standards New Zealand, 2018 (AS ISO 31000:2018)

AS ISO 31000:2018 *Risk management – guidelines* provides detailed instructions on how to set out and implement a risk management process. The following information shows how the standard can be applied to planning and operating for integrated closure, with a particular emphasis on how social opportunities may be captured using the same framework that is typically used to manage hazards or threats. The risk management standard is a comprehensive document with considerably more contextual information and should be referred to in association with this tool. This tool details an application of the standard to closure. This approach can be used by companies that do not have their own standards for risk assessment and guidance on acceptable levels of risk.

This tool can be used for the following:

— to evaluate issue-specific (eg biodiversity, community health) risks or opportunities, and the impact of its management, or

— to evaluate, based on specific closure objective, the risk that the objective will not be met, and the impact of subsequent management on that risk.

Terms used in risk assessment

Term	Definition
Risk	Effect of uncertainty on objectives. Risk is usually expressed in terms of risk sources, potential events, their consequences and their likelihood
Residual risk	The remaining risk after management actions have been implemented to reduce the initial risk
Latent risk	Those risks that are unknown or that are not imminent
Likelihood	The chance of something happening. In risk management it may be measured or determined objectively or subjectively, qualitatively or quantitatively, and described in general terms or mathematically
Consequence	The outcome of an event affecting objectives
Event	The occurrence or change of a particular set of circumstances
Control	Measure that maintains and/or modifies risk

It is important that these risks are workshopped by a multidisciplinary team with the appropriate range of technical expertise so that an agreed rating can be determined.

Likelihood and consequence scales for risk and opportunity

In calculating the pre-mitigation rating of each impact, presuming a worst-case scenario, the likelihood for each risk event occurring for each impact needs to be agreed upon. The table below provides a description of the likelihood ratings.

Likelihood rating of the risk occurring

Likelihood	
Almost certain (5) **>90%**	Greater than 90% likelihood of occurring Has happened, will probably happen during the mine life and there is no reason to suspect it won't happen
Likely (4) **30%–90%**	Likelihood of occurring is equal to or more than 30% and less than 90% This consequence is not uncommon in the mining and metals industry/area
Possible (3) **10%–30%**	Likelihood of occurring is equal to or more than 10% and less than 30% There is a possibility of this risk occurring as it has occurred before (albeit infrequently) in the mining and metals industry/area
Unlikely (2) **3%–10%**	Likelihood of occurring is more than or equal to 3% and less than 10% There are no specific circumstances to suggest this could happen
Improbable (1) **<3%**	Likelihood of occurring is less than 3% It would require a substantial change in circumstances to create an environment for this to occur, and even then, this is a rare occurrence

The consequence of the risk event also needs to determine the severity factor for each impact type, including:

— schedule

— financial

— safety

— environment

— legal and regulatory

— social/communities

— reputation.

The table below shows an example of the consequence ratings should various types of risks occur. Note that for this table and the previous one, examples are shown, but the content of these tables can be redefined to suit the circumstances and risk sensitivity of any organisation.

Consequence rating of the risk occurring

Consequence rating					
Consequence type	Insignificant (1)	Minor (2)	Moderate (3)	High (4)	Major (5)
Schedule	Less than 1% impact on overall project timeline	May result in overall project timeline overrun of equal to or more than 1% and less than 3%	May result in overall project timeline overrun of equal to or more than 3% and less than 10%	May result in overall project timeline overrun of equal to or more than 10% and less than 30%	May result in overall project timeline overrun of 30% or more
Financial	Less than 1% impact on the overall budget of the project	May result in overall project budget overrun of equal to or more than 1% and less than 3%	May result in overall project budget overrun of equal to or more than 3% and less than 10%	May result in overall project budget overrun of equal to or more than 10% and less than 30%	May result in overall project budget overrun of 30% or more
Safety	First-aid case	Medical- treatment case	Lost-time injury	Permanent disability or single fatality	Numerous permanent disabilities or multiple fatalities
Environment	Lasting days or less; affecting small area (metres); receiving environment altered with no sensitive habitats and no biodiversity value (eg urban/industrial areas)	Lasting weeks; affecting limited area (hundreds of metres); receiving environment altered with little natural habitat and low biodiversity value	Lasting months; affecting extended area (kilometres); receiving environment comprising largely natural habitat and moderate biodiversity value	Lasting years; affecting area on sub-basin scale; receiving environment classified as having sensitive natural habitat with high biodiversity value	Permanent impact; affecting area on a whole basin or regional scale; receiving environment classified as highly sensitive natural habitat with very high biodiversity value
Legal and regulatory	Technical non-compliance. No warning received; no regulatory reporting required	Breach of regulatory requirements; report/involvement of authority. Attracts administrative fine	Minor breach of the law; report/ investigation by authority. Attracts compensation/ penalties/ enforcement action	Breach of the law. May attract criminal prosecution, penalties/ enforcement action; individual licence temporarily revoked	Significant breach of the law. Individual or company lawsuits; permit to operate substantially modified or withdrawn
Social/ communities	Minor disturbance of culture/social structures	Some impacts on local population, mostly repairable. Single stakeholder complaint in reporting period	Ongoing social issues. Isolated complaints from community members/ stakeholders	Significant social impacts. Organised community protests threatening continuity of operations	Major widespread social impacts. Community reaction affecting business continuity. Licence to operate in jeopardy
Reputation	Minor impact; awareness/ concern from specific individuals	Limited impact; concern/ complaints from certain groups/ organisations (eg NGOs)	Local impact; public concern/ adverse publicity localised within neighbouring communities	Suspected reputational damage; local/ regional public concern and reactions	Noticeable reputational damage; national/ international public attention and repercussions

The risk level is identified based on the likelihood that an event occurs, and its consequence. Using the previous two tables for input as the number of likelihood and consequence categories, the following risk-level matrix can be developed. The decision as to how to categorise the various levels of risk shown in the matrix also depends on the circumstances and risk sensitivity of any organisation.

Risk-level matrix

Likelihood	Consequence scale				
	Insignificant	Minor	Moderate	High	Major
Almost certain >90%	11 (Medium)	16 (Significant)	20 (Significant)	23 (High)	25 (High)
Likely 30%–90%	7 (Medium)	12 (Medium)	17 (Significant)	21 (High)	24 (High)
Possible 10%–30%	4 (Low)	8 (Medium)	13 (Significant)	18 (Significant)	22 (High)
Unlikely 3%–10%	2 (Low)	5 (Low)	9 (Medium)	14 (Significant)	19 (Significant)
Improbable <3%	1 (Low)	3 (Low)	6 (Medium)	10 (Medium)	15 (Significant)

Sishen mine open pit look out, South Africa

Tool 9: Considerations in Developing Closure Activities for Transversal Issues

This tool provides basic background for consideration in developing closure activities for transversal issues, as well as some suggestions on where to find additional support.

River diversion at Isibonelo Colliery, South Africa

There are aspects of closure planning that cover all components of the site. Social transition activities are undertaken to facilitate or ease the social transition from the operational to post-closure phase, and inherently apply to the whole mining operation.

Water management also needs to be addressed on a site-wide basis and may also have off-site implications. While aspects of water management will be tied to individual site domains, an integrated approach to water management based on an understanding of water movement over the whole of the site and off-site is necessary.

Ecosystem establishment of the site through techniques such as revegetation is also addressed as a transversal issue. While there will likely be differences in how and why ecosystems are established in individual components of the site, programmes for ecosystem establishment are usually developed on a site-wide basis, informed by a common ecosystem or set of geographically linked ecosystems (although it can also be developed by domain).

Social transition activities

Social transition management and mitigation designed for the active operation phase can continue being applied into the closure transition process and post-closure. Examples of management activities that may be implemented during the life cycle and mechanisms to achieve those are presented in the table below.

Considerations in developing social transition activities

Activity	Example mechanisms
Closure communications management	— Develop a communications plan that outlines key messages about the project closure process, proposed consultation timing and location, and grievance redress mechanisms. — Include closure in messaging for the start of a project, including clear indication of the finite nature of the mine life, and the variety of factors that can affect its duration.
Social investment/ community development strategy	— Support livelihood diversification programmes (eg agricultural diversification, aquaculture improvement). — Improve food security (if a local issue) by prioritising final land use planning and rehabilitation that support food security (eg arable land and improvements in irrigation productivity). — Provide local business development and entrepreneurial support beyond procurement of goods and services to the mine (eg establish supply chains for locally produced goods and services independent of the mine acting as a primary customer/consumer). — Support programmes that provide access to financial services through community-based banks or microfinance (eg provide technical support and opportunities for training, find suitable NGOs for implementation). — Develop and/or support programmes aimed at assisting vulnerable groups in preparing for and transitioning through closure. — Implement a programme of support to local suppliers and/or further develop existing initiatives to ease the transition to closure. — Use the knowledge base/studies/monitoring and data to improve agricultural capacity of communities. Water in particular is a critical issue. Concerns about lack of water may in some cases be addressed through better management of resources.
Local government development	— Support local government development initiatives. — Support training centre(s) and/or programmes.
Employment and skills development	— Provide training and skills transfer. — Develop specific training programmes towards the end of operations aimed at improving skills specifically related to other opportunities/businesses in the region (personal finance, entrepreneurship, small-scale business, etc) as a way to prepare employees for change. — Support education opportunities through scholarships, site-based placements, etc. — Develop and implement preferential local recruitment policies for operations and closure to maximise employment opportunities for local communities. — Develop a retrenchment plan, which could include staggering the workforce reduction over time to minimise impact on local community socioeconomic conditions (eg demographics, economy) and employees.

For any of the example activities and mechanisms presented above, it is important to understand the demographic profile of affected stakeholders and their existing livelihood strategies to identify opportunities specific to different categories of stakeholders.

Water management

By the time a mine reaches the end of its productive life, the pre-mining baseline context is likely to have been significantly altered through physical changes made during operations. These alterations can include activities such as diversion of watercourses, water removal, discharges, or groundwater pumping for process use and/or dewatering of mining areas. Mine voids (such as pits) and mine waste facilities (such as tailings storage facilities) can significantly impact both the pattern of surface and groundwater flow and its quality, both on-site and off-site. Ongoing documentation of the knowledge base should serve as a reference point for understanding alterations during the mine life, and for the design of closure activities.

Many mining companies have been working on strategies to reduce the impact of water-related risks (availability, consumption, dependency). ICMM has established a water stewardship position statement that all members must commit to and has issued supporting tools such as the *Water Stewardship Maturity Framework (2023)* and the *Water Reporting:*

Good Practice Guide (2021). The management of water has transitioned from an internally focused operational consideration to a more holistic approach that considers the broader needs of the surrounding catchment/watershed, its ecosystem, dependent communities and other users. As such, these issues should form an integral part of stakeholder communication and planning for closure activities.

Implementing activities to address water management needs can be a significant closure cost, a major source of technical uncertainty, an area for the most stringent regulatory requirements and one of the most contentious issues for surrounding communities. It is also one of the areas where it is usually necessary to consider the impacts of climate change. The design and selection of closure activities for water management needs to provide an integrated approach for addressing site-wide issues, balanced with solutions that are specific to individual installations.

Details on typical water management closure activities are provided in the following subsections.

Assessment and management of a site-wide water balance

A site-wide water balance is typically developed during mine design to provide an overall understanding of water movement at the site during operations. This water balance is a fundamental tool for closure design. A site-wide water balance is often used to evaluate the impacts of different closure options. It is typically developed as a numerical model. Site-wide water balance models often include linkages with more detailed water management models, such as hydrogeological, seepage and watershed flow routing models. Geochemical models are also often linked to water balance models to add a water quality component to the water balance. These models typically use many assumptions, and it is good practice to consider outputs in terms of ranges or conduct sensitivity analysis, rather than consider results as deterministic outputs.

Water management will normally have a physical component for the management of water movement, as well as an interrelated chemical component for the management of water quality.

Implementation of physical activities

Closure water management activities that relate directly to the physical movement of water include:

- constructing engineered structures to direct water flow over or divert water around the site, including spillways, swales, ditches and other structures
- upgrading operational structures in consideration of long-term success criteria (eg water diversions built considering a 1-in-50-year storm event may need to be upgraded to accommodate a 1-in-200-year event if that is the success criteria)
- development of surface drainage features that control erosion through forms that are analogous to natural drainage features (using the principles of geomorphic design)
- restoration of pre-mining drainage features, such as streams and creeks removal of temporary water control structures (culverts, roadside ditches, and sediment or diversion dams), to restore pre-mining water flow patterns
- potential community interactions such as transferring the ownership of potable water wellfields or assessing the impacts of the end of dewatering on water supplies
- changes to downstream infrastructure since mining commenced and how that relates to dischargeable volume at closure.

Addressing impacts or potential impacts on water quality

Mine waste facilities or other impacted lands can affect the quality of downgradient surface water and groundwater. Not all impacts are necessarily unacceptable, and part of the evaluation of applicable closure activities should include both prediction of potential impacts and evaluation of the effects of those impacts.

The 'source–pathway–receptor' model can be used to help identify potential impacts to water quality. If water quality impacts appear to be unacceptable, the model can then be used to help identify management approaches for breaking the pathway (divert, treat). The source–pathway–receptor model is shown and described in more detail in the figure below.

The Source–Pathway–Receptor Model

Source

– Identify potential sources of contaminants to water, including:
  - acidic mine waste
  - metal-impacted soils
  - fuel spills
  - process chemicals
– Characterise/predict the effect of contact with mine waste on water quantity

Pathway

– Identify pathways between the source and potential receptors. This may be surface water, groundwater or combinations of both

Receptor

– Identify potential receptors:
  - human
  - environmental
– Evaluate potential impacts of predicted concentrations on the receptors

The source–pathway–receptor model

With a clear understanding of the pathways, mitigations can be considered, for example:

— Take steps to isolate the contaminant and to prevent or minimise the amount of contact water (surface water diversions, covers, footprint minimisation, waste segregation).

— If there is a pathway, evaluate approaches to address contaminant movement (barrier walls, grout curtains, pumping wells).

— Evaluate methods to change contaminant concentrations in the pathways (active treatment, passive treatment, reactive permeable walls, etc).

— Evaluate water use changes or restrictions to eliminate receptors.

There are many potential contaminants that may need to be evaluated on a site-specific basis. Some of the more commonly encountered issues are:

— **ARD/ML:** This is discussed in more detail in the subsection below.

— **Nutrients:** Use of standard explosives can leave waste rock with nitrogen residues that may impact surface water quality. These can be difficult to quantify without site-specific data.

— **Non-metal leaching:** There are a variety of non-metals that can negatively impact water quality. Selenium, cyanide and sulphates are all examples of non-metals that can be encountered in mining wastes and may need to be addressed in water management.

— **Salts:** Increased concentrations of salts in water, with saltwater contamination of freshwater, can be a significant water management issue. Some deep mining operations can bring saltier deep groundwater to the surface, and this water may need to be managed, both during operations and during closure.

— **Hydrocarbons:** Mine activities can result in areas of hydrocarbon contamination, with the risk to affect water quality.

Strategies to prevent acid rock drainage/metal leaching issues

ARD/ML on an industry-wide basis is a widely recognised risk and potential source of ongoing residual risk and financial liabilities post-closure. At sites where this is a risk, operational and closure activities must be developed to prevent or mitigate ARD/ML.

ARD/ML results from water contacting geochemically reactive materials such as certain types of waste rock, tailings and pit walls. Acid drainage is a common issue of concern, but neutral (or even alkaline) drainage with elevated metals concentration, or neutral but impacted with salts, can be of equal concern.

Acidic drainage often contains significantly elevated metals and metalloid concentrations. Oxygen is important in initiating acidic drainage development, but once started, the reactions do not necessarily require exposure to oxygen in the air to continue. Acid production can continue for millennia until either the acid-generating mineralogies are exhausted or some form of source/pathway control is enacted.

All mine waste materials should be geochemically characterised to predict if ARD/ML will be generated. *The Global Acid Rock Drainage (GARD) Guide*[5] provides a comprehensive and authoritative resource in making such predictions.

The preferred strategies (in order of typical preference) to prevent ARD/ML issues are:

1. **Limit the exposure** of unoxidised potentially acid-forming material to oxygen to limit the rate of acid generation. This can be done by immersion in water (subaqueous disposal) or by placing a cover that restricts the flow of oxygen and limits the migration of water through the system.
2. **Prevent ARD/ML generation** by avoiding contact between reactive materials and water.
3. **Prevent transport** from the ARD/ML source to sensitive receptors.
4. **Neutralise ARD/ML** with neutral or alkaline materials.
5. **Treat ARD/ML-impacted water.**

Typically, the number of alternative closure activities available is greatest early in the asset life- cycle stages, with less flexibility if operations are significantly under way or solutions need to be designed nearer the date of closure. Water treatment is listed last in the order of preference as it typically results in a long-term liability and may impede relinquishment of the site.

Assessment and implementation of water treatment systems

At some sites, long-term water treatment may be required as part of the closure plan when water quality would otherwise fail to meet success criteria. Even when long-term water treatment appears to be a cost-effective solution to water quality concerns (when evaluated on an NPV basis), there are a number of reasons why mining companies (and regulators) prefer to avoid it:

— the typically very long-term nature of treatment requirements, generating residual risk

— the difficulty in accurately predicting the true duration needed for treatment

— conflict with finite funding and management resources that may be available following closure

— the risk of underestimating the true treatment needs and costs

— future changes in effluent regulations that could increase treatment complexity and costs

— risks and impacts if treatment underperforms or treatment funding is discontinued

— the common view that long-term water treatment is incompatible with relinquishment of the mine, unless innovative arrangements can be found

— the need to maintain financial assurance with the regulator that is sufficient to cover the cost of ongoing treatment

— long-term generation and disposal of water treatment by-products/brines.

At some sites there may not be an alternative. The most commonly used approaches for water treatment are active and passive treatment, with numerous possible hybrids of the two:

Water treatment plant at closed Sullivan mine, Canada

5. Source: http://www.gardguide.com/index.php?title=Main_Page

- **Active treatment:** Active treatment systems include mechanised systems and a variety of processes for the treatment of mine water, including aeration, neutralisation, metal content precipitation, metals removal, chemical precipitation, membrane processes, ion exchange and biological sulphate removal. They typically require ongoing inputs of energy, supplies and staff for daily operation and maintenance, including management of sludges or brines.
- **Passive treatment:** Passive systems include different treatment systems that use natural processes for the removal of contaminants of concern and operate without power or chemical supplies (although they may need periodic replenishment of spent media). Anaerobic reducing cells, wetlands and reactive channels are all passive treatment systems.

Active, passive and hybrid systems should be designed and evaluated by specialists. The evaluation process typically includes technology screening, laboratory scale studies and pilot plants prior to full-scale implementation. The identification of the preferred system will depend on site-specific conditions such as flow rates, flow variability, contaminants of concern, climate, receiving environment characteristics and land availability. Passive systems typically offer lower ongoing operating and maintenance requirements, but with greater land requirements, less process control, more climate sensitivity and less flexibility in the contaminants that can be treated. Passive treatment systems are not 'walk away' solutions and will require periodic renovation and maintenance.

The GARD Guide provides additional discussion of common treatment technologies for mine water.

If ongoing water treatment is required, there may be benefits. These can include:

- continued employment opportunities and contribution to the local economy
- promotion of continual site presence, which promotes adequate capacity for ongoing site inspection, maintenance and management capability for the closed site
- reasonable closure outcomes for installations that may not be practicably closed otherwise
- possible benefits of combining the treatment of mine water with other treatment requirements of the local community on an ongoing basis
- residual value of treated water or by-products generated from the water treatment process.

Ecosystem establishment

Revegetation is a closure activity that is applicable site-wide and is commonly used as the basis to achieve a variety of closure objectives such as:

- erosion control
- ecosystem establishment
- evapotranspiration/infiltration objectives
- preparation of land for post-closure use
- meeting biodiversity goals (flora and fauna)
- aesthetics.

Different methods of revegetation may be applied at different areas within the site to achieve different objectives. While it is not always technically and economically feasible to actively revegetate closed sites, it is commonly either strongly advocated for by stakeholders or legally mandated.

Revegetation activities can be classed as either active, where seeds or plants are placed on the target surfaces, or passive, where some degree of ground preparation may be undertaken but the vegetation is expected to propagate over the disturbed areas naturally.

In designing revegetation programmes, the following site-specific factors typically need to be considered:

- **Climate evaluation:** The possibilities and limits for revegetation are controlled in large part by the climate. There are sites where revegetation of lands disturbed by mining activity is not practicable or in keeping with the surrounding ecological conditions (eg at sites in the High Arctic or extreme desert environments). At other sites, such as in the tropics, it would be difficult to prevent vegetation from encroaching on disturbed lands after closure. Between those two extremes, there are many sites where revegetation requires careful management and planning to meet closure objectives and success criteria.
- **Direct revegetation:** There may be an opportunity to revegetate directly on mine wastes or disturbed areas. Success has been demonstrated with direct revegetation of both waste rock and tailings, although these successes are dependent on site-specific conditions. The possibility of this should be evaluated, especially where there are limitations on the available soil substrates to support revegetation.
- **Soil salvage:** It is now standard practice to recognise organic soils as a valuable and scarce resource, one

that should be secured from the site prior to mining or the construction of mine waste facilities and safeguarded for rehabilitation.

— **Soil stockpiling:** Stockpiles are used to store salvaged soil until it is needed to support revegetation. Soil characteristics will change over time in a stockpile, tending to become less viable as an organic substrate. Soil stockpiles should be designed and managed to minimise the loss of soil viability over time. This typically includes activities such as minimising the height of the piles and ensuring that they are stabilised with vegetation until they can be used.

— **Direct soil placement:** It may be possible to avoid soil stockpiles – and the associated loss of soil viability over time – through direct placement of salvaged soil on another part of the site in support of revegetation. This also provides the benefits of progressive closure, and an economic benefit by reducing double handling of the soil. Direct soil placement requires confidence that the placed soil will not be disturbed again in the future.

— **Substrate deficiency:** If insufficient stockpiled soil is available to address revegetation needs, there are several approaches available to provide suitable substrates for revegetation purposes. Mine wastes, such as inert tailings or inorganic mineral soils, may be combined with other materials to provide a substrate. Organic matter (eg water treatment by-products, peat, manure, agricultural waste, mulch) can be combined to generate substrates that will support revegetation efforts. Fertilisers, chemical amendments and soil conditioners can all play roles in developing functioning substrates. Species selection can also be used to help condition the substrate and prepare it for further use (ie nitrogen-fixing plant species can be used to condition soil).

— **Species selection:** The plant species to be used in revegetation efforts should be selected based on site-specific analysis by qualified specialists. In the early stages of revegetation, the terrain to be revegetated is likely to be distinct from the surrounding ecosystems, and species should be selected to put the terrain on a trajectory towards the desired final land use.

— **Research:** The development of revegetation programmes benefits greatly from research work and collection of data, typically through progressive closure. There should ideally be years of experience leading up to closure to test alternative approaches; evaluate seed mixes, seeding methods and seedbed preparation; and undertake preparation of the seed banks needed for closure.

— **Engagement:** The design and testing of revegetation approaches for the site provide engagement opportunities. These can include engagement related to the definition of desired plant species for final land use, and an opportunity to demonstrate visible progress towards closure. Where indigenous communities are present, they can also present an opportunity to inform the development of revegetation programmes with traditional knowledge.

— **Ongoing management:** The establishment of self-sustaining vegetation can take years to accomplish, and natural succession of species on revegetated terrain may result in a process that takes decades (progressive closure activities can provide early demonstration of this trajectory). In typical practice, ongoing management is needed to ensure that revegetation efforts are well established and sustainable. This may include activities such as reseeding, weed control, erosion repair, and short-term nutrient addition or irrigation. Monitoring may be significantly limited or completed once it has been demonstrated that the revegetated system is on a stable and desired trajectory. This type of control may generate a long-term management need.

Care and attention should be given to effective revegetation and to tracking and documenting the results of work carried out.

Tool 10: Considerations in Developing Closure Activities for Domain-Specific Issues

This tool provides basic background for consideration in understanding some of the most common closure activities for each of these three domains, as well as some suggestions on where to find additional support.

At the most basic level, the physical components of a mining operation to be addressed in a closure plan are:

— **Mine voids:** the openings generated by the mining of material, which include pits, subsidence areas, shaft openings and adits, and underground workings.

— **Mine waste:** waste material generated after the extraction of the ore, including processing by-products (such as tailings, spent heap leach material) and waste rock.

— **Mine infrastructure:** structures and facilities constructed to support mining activities, including elements such as processing facilities, offices, roads, pipelines, power supplies, culverts and laydown areas.

Together, these components make up the physical site aspects subjected to intervention and will need to be addressed in the closure plan.

Note that domains should also be evaluated together and interactions between them considered. The best solution at a given site may combine domains. As an example, disposing of reactive tailings below the water table in an open pit (a mine void) may be the best closure solution for both installations.

Mine voids

The main types of mine voids are underground mine workings and open pits. Underground mine workings include openings to the surface such as vents, raises, stopes and shafts. Subsidence areas generated as a surface expression from the collapse of underground openings are another type of mine void. These can be generated both intentionally and unintentionally.

While there are considerable differences in the closure activities applicable to the different types of mine voids, they all share concerns over risks to humans and wildlife associated with falling into the opening or otherwise becoming trapped in it. As the potential consequences of such an incident are high, closure activities to control access are a common requirement for mine voids.

Details on typical closure activities for both underground mines and pits are provided in the following subsections. The closure of subsidence areas may be analogous to pit closure, although backfilling approaches are more common for subsidence issues.

Underground mine workings

While there are many exceptions and site-specific considerations, the activities to close underground mine workings have become more standardised. A typical procedure involves the following:

— **Hazardous material removal:** Remove all potentially hazardous material from the underground, such as hydrocarbon products, chemicals and explosives. The focus is usually to remove material that has the potential to significantly impact water quality when (or if) the underground is flooded.

— **Salvageable material removal:** Remove materials that can be safely and economically salvaged from the underground. Once hazardous material is removed, the decision to remove other material from the underground should be an economic one, driven by the balance between the cost of removal and the economic benefit of its reuse or scrap value.

— **Backfilling:** While not a standard approach, consideration may be given to backfilling some or all of the underground voids with tailings, paste tailings (including cemented paste) or similar materials. This may be undertaken to provide additional support to the voids where there is a risk of subsidence, especially where subsidence is not compatible with the planned post-closure land use. This may also provide a benefit as a preferred disposal location for the tailings.

— **Flooding:** Underground mining is often carried out below the groundwater table, facilitated by dewatering activities. Dewatering is normally terminated as part of closure, and the underground workings flooded or partially flooded as water returns to steady-state levels.

— **Access control:** Openings to the surface are typically blocked off by collapsing openings with explosives; placing rockfill; using combinations of expanding foams and rockfill, grout or grouted plugs, and concrete fill or reinforced concrete caps; and constructing gates/lockable caps where post-closure access to the underground is required. Consideration should be given to the design life of the engineered feature, including the future replacement cost.

— **Water management:** Depending on the configuration of the openings and the site hydrogeology, there may be either intermittent or ongoing water discharges from the underground mine openings. Management approaches will depend on flow rates and the current and expected chemical composition of the discharge.

Open pits

Open pits can require implementation of closure activities to control a variety of physical and chemical risks.

Issues around physical access control are commonly addressed with perimeter berms to discourage inadvertent or unauthorised access, and/or with blockage of the access roads. As pit walls are often not developed with long-term stability in mind, geotechnical/rock mechanics studies should be undertaken of the final pit configuration at the time of final closure. These studies can be used to identify a safe setback distance for the berm so that the access control is located outside of the expected long-term extent of the pit.

At some mines where there are multiple pits, integrated closure planning may facilitate backfilling of pits with mine waste. This can provide benefits for physical (and possibly chemical) stability of the waste facilities. While backfilling of pits is often raised as a potential closure activity, it is normally not cost-effective unless combined with waste disposal from active mining operations, such as may be practical with the sequencing of a strip-mining programme.

Pit lakes may form after the end of operations. When dewatering activities were needed to keep the pit dry in operation, the end of dewatering can lead to accumulation of water in the open pit, effectively forming a lake.

Pit lakes can create significant residual risks at closure since they often have steep sides, great depths and large volumes, and may attract people. Depending on the deposit nature and management practices, the large volume of water in the pit may also be contaminated, presenting additional closure challenges. However, unlike many other closure landforms, pit lakes can offer substantial benefits. Properly managed with regard to the change in land type from terrestrial (pre mining) to aquatic (post-mining), pit lakes can present opportunities for beneficial post-closure use.

The selection of closure activities for pit lakes typically involves the integration of social, environmental and economic viewpoints. Long-term water quality is key to pit lake closure planning, with good water quality generating additional options for beneficial post-closure pit lake use.

Some common beneficial closure approaches for pit lakes, listed in the order of increasingly stringent requirements for pit water quality, are:

— site-impacted water control

— water storage and flood mitigation

— hydro energy generation

— recreational use and aesthetics

— aquaculture and fisheries, agriculture

— ecological habitat.

When the water quality is predicted to be poor, water treatment may be needed. This may be either in-pit treatment (such as periodic dosing with lime) or water treatment systems or some combination of the two. In some cases, poor water quality is associated with oxidation of acid- forming materials on pit walls. While placing covers on pit walls is occasionally proposed as an option for addressing this, the geometry of most pit walls means that this approach is seldom, if ever, practical in the long term. LoM planning should seek to avoid exposing these materials if possible.

The climate and local hydrogeology have a significant influence over pit lake closure activities. In very dry climates, the pit lake may never have any outflow, and the pit will remain a groundwater sink. In wetter climates, pit lakes may eventually overflow, either seasonally or consistently. Water management approaches will be determined based on the tendency to overflow or not. The time taken for pits to fill can present a post-closure management challenge. It is not uncommon for pit filling to take 20 to 80 years or longer. This can impact approaches for post-closure land use, monitoring durations and relinquishment.

Collahuasi copper mine, Chile

Mine waste

Costs to close mine waste installations can be high depending on chemical and physical stability of the waste and how large an area it occupies.

The most common types of mine waste are:

— tailings

— waste rock

— heap leach piles

— slag and process residues.

Proper design and closure of mine waste facilities requires that the waste materials be characterised with respect to their physical and chemical properties, based on adequate geotechnical and geochemical testing on the waste materials.

Closed mine waste facilities will typically have a long or indefinite design life as they will remain in place for the foreseeable future. Closed mine waste facilities often need to be stable in the long term with infrequent or no human intervention. Further, the long/indefinite duration of the design life means that it is much more likely that the facility will eventually be exposed to extremely infrequent events, such as large earthquakes or floods.

Given this, the design criteria used to establish the physical stability of mine waste facilities are usually more stringent after closure than during operation. Some guidance documents recognise this explicitly.

The use of more stringent design criteria after the mine operations phase implies that activities to stabilise mine waste facilities may need to be undertaken as part of implementing closure (eg constructing stabilisation berms on tailings dams, enhancing spillway capacity or flattening waste dump slopes). For mines in the planning phase, it is usually more sensible to adopt a 'design for closure' approach. In other words, the mine waste facilities should be designed with eventual closure needs in mind, and then developed to fit the post-closure design criteria. This approach will reduce the additional effort that may be needed to stabilise the facilities at closure, reducing the overall cost of closure activities.

The following subsections provide additional detail of the closure activities specific to different types of mine waste facilities, with a focus on the two key guiding principles for physical and chemical stability. These are not the only concerns to be addressed by closure activities. Factors that could significantly shape the design and closure of the facilities include future land use, desired landform shapes, aesthetic values to stakeholders and interests of future parties at relinquishment.

Tailings facility closure

Operating tailings storage facilities in a manner consistent with closure objectives is relevant at every stage of the mine life cycle. Progressive closure, closure and post-closure planning should begin at the outset of the mine life cycle. For existing facilities, setting closure objectives is important to ensure successful and safe outcomes for owners, operators and project stakeholders. ICMM's *Tailings Management Good Practice Guide (2025)*, Section 3.7 Closure and Post-Closure provides tailings-specific considerations for the development and execution of closure and post-closure phases of the mine life cycle. Attention should be given in the early design stages to selecting the tailings technology that is most appropriate for all stages of the design life, including closure.

There are numerous options available for the management of tailings, including tailings storage facilities with containment dams, dry stack tailings and disposal in mine voids. The option selected will have a profound influence on the post-closure performance of the facility in terms of physical stability, chemical stability, public safety and land use.

Governance of tailings storage facilities during closure and post-closure

Effective governance is essential to both safe and responsible operations and the closure of tailings storage facilities. In the early stages of the mine life cycle (or as early as possible for operating facilities) an effective tailings governance framework should be put in place. ICMM's *Tailings Management Good Practice Guide (2025)*, Part 2: Governance of Tailings Management, details the organisational structures, processes and procedures to promote effective management for tailings storage facilities. While closure governance and tailings governance may have shared objectives, the governance structure for closure of tailings storage facilities may differ at a company or individual site level. There is considerable guidance available on the makeup on tailings facility governance structures, including in the GISTM. The ICMM *Tailings Management Good Practice Guide* also provides support on the process for integrating the recommended governance framework throughout the life cycle, including closure and post-closure phases.

Table 2 summarises key closure-related responsibilities of various roles in the tailings governance framework. While responsibility for various elements of closure of a tailings storage facility ultimately sits with the individuals identified in Table 2, regular engagement between these practitioners with the Closure Committee Closure Champion (refer to Table 1) are critical to ensure integration of closure considerations throughout life of asset.

Table 2: Key roles and responsibilities related to closure of a tailings storage facility

Role	Description	Closure-related Responsibilities
Accountable Executive	— One or more executives who is/are directly answerable to the CEO and accountable for the safety of the tailings storage facility.	— Delegate responsibility and authority for the development of integrated closure plans to ensure facility integrity post-closure. — Advocate for resources needed for tailings management across all mine life stages, including closure.
Responsible Tailings Facility Engineer	— An engineer appointed by the operator to be responsible for the tailings storage facility. — Responsible for the scope of work and budget requirements for the tailings storage facility, including risk management. — Ensures the tailings storage facility is designed, constructed and decommissioned appropriately (jointly with the Engineer of Record).	— Ensure the development of the tailings storage facility closure plan in collaboration and alignment with professionals responsible for the development of the site-wide closure plan. — Ensure the implementation of progressive closure as practical during operations phase. — Ensure the implementation of the tailings storage facility closure plan at the end of the Operations phase in line with the site-wide closure plan. — Identify when and where contemplated operational changes are a potential deviation from the design intent and engage the Engineer of Record or Design Team as part of the process to manage change. — Implement measures to remedy variances from performance and closure objectives or criteria.
Engineer of Record	— A qualified engineering firm or individual engineer responsible for confirming that the tailings storage facility is designed, constructed and decommissioned appropriately.	— Provide engineering analysis in support of the development of the tailings storage facility closure plan. — Participate in the development of the risk management plan, including risk controls, critical controls and associated surveillance. — Develop and maintain relevant records related to maintenance, surveillance and closure.
Independent Tailings Review Board	— A board that provides independent technical review of the design, construction, operation, safe closure and management of tailings storage facilities.	— Review and provide input on the alternatives analysis of closure strategies for tailings management. — Confirms safe closure[6] when a tailings storage facility is found to not pose ongoing material risks to people or the environment. — Provides input on the current or anticipated performance of the development and implementation of the closure plan as it relates to tailings management. — Provides independent assessments of technical issues associated with the closure of tailings storage facilities and associated structures including diversion channels, water management structures, progressive closure opportunities and overall water management. — Engages and seeks input from additional subject matter experts relevant to closure when situations warrant additional collaboration.

6. The GISTM defines 'safe closure' as a closed tailings facility that does not pose ongoing material risks to people and the environment, and which has been confirmed by an Independent Tailings Review Board or senior independent technical reviewer and signed off by the Accountable Executive. The ICMM *Tailings Management Good Practice Guide section 3.7.4.1* provides support for the process of transitioning active facilities to responsibly closed facilities.

Design of closure activities for physical stability of tailings storage facilities
Closure activities for tailings storage facilities should consider and address the potential modes of failure that could occur post-closure including those summarised in **Table 3** below.

Tailings dam failures have resulted in catastrophic environmental damage and loss of life, and recent history suggests that inadequate design, construction and maintenance continue to result in catastrophic failures (see ICMM's 2016 *Position statement on preventing catastrophic failure of tailings storage facilities*). There is considerable technical guidance available on the design and operation of tailings dams, and accepted industry guidelines should be used, such as the documents produced by GISTM, the Canadian Dam Association (CDA)[7] or the Australian National Committee on Large Dams.

Tailings dams typically remain as permanent structures after mine closure, and closure activities should be developed to properly address and control the identified risks. Dams that remain medium- to high-risk structures (in CDA classifications) after closure should have post-closure operation, maintenance and surveillance (OMS) plans and emergency preparedness plans in place. The development on an OMS manual should be informed by a range of references and tools. including Section 2.4 in ICMM's *Tailings Management Good Practice Guide* (2025).

Design of closure activities for chemical stability of tailings storage facilities
Tailings are usually physically contained within a mine site. Unacceptable environmental impacts from tailings usually relate to the discharge of tailings contact water off-site into a receiving environment such as a groundwater or surface water resource, or wind-blown dust impacts on the surrounding environment. Tailings are the uneconomic end product of processing ores, which by nature are enriched in mineralisation and may be at risk of generating ARD/ML.

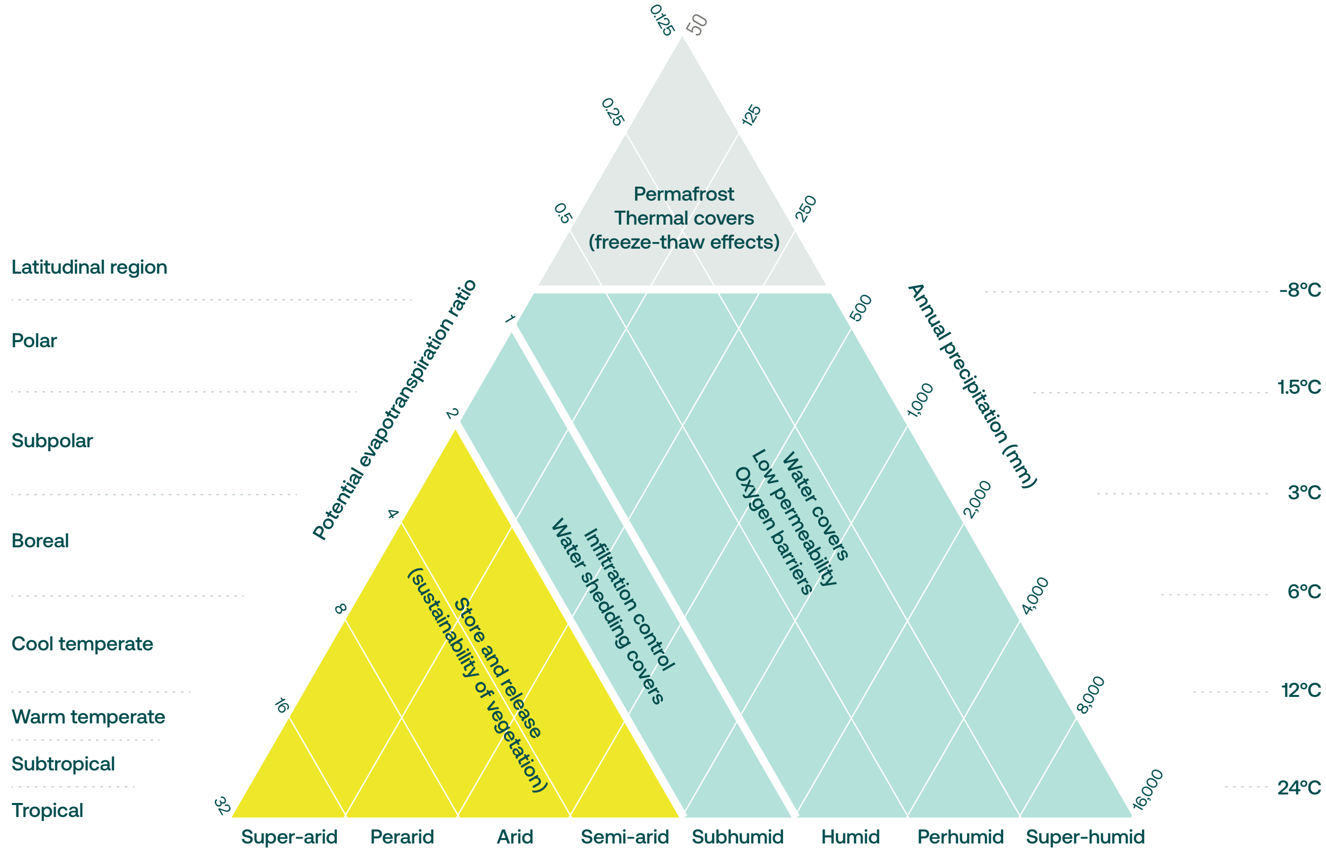
It is vital for design that the geochemistry of tailings be thoroughly characterised (refer to the GARD Guide for appropriate protocols for geochemical characterisation of tailings), and the evaluation of closure needs to be considered in the context of planning for site water management.

Table 3: Closure activities for various modes of failure for surface tailings impoundments

Possible mode of failure	Disruptive agent	Closure activities
Overtopping	Extreme rainfall or snowmelt, blocked spillway	Increase capacity of emergency spillway if necessary; inspect and clear spillway
Dam instability	Loading from earthquake	Design geotechnical stabilisation activities such as a toe berm
Dam instability	Rising phreatic surface in downstream	Monitor and clean or augment drains as necessary; reduce pond water level
Dam instability	Tailings liquefaction	Design geotechnical stabilisation activities such as a toe berm or buttress
Wave erosion	Wind storm and high pond water level	Lower spillway (or breach dam if possible); place larger riprap
Runoff erosion	Runoff from rainfall	Monitor, repair and enhance vegetative cover or erosion protection
Wind erosion	Wind storms	Monitor, repair and enhance vegetative cover or erosion protection

7. Particularly relevant is the CDA (2013) Dam safety guidelines 2007 (2013 edition) and the CDA (2014) Technical bulletin: application of dam safety guidelines to mining dams.

Cover types for different climates



Source: Wickland et al 2006[8]

During mine operations, when reactive tailings are present, water treatment and/or pump back systems are often used to mitigate impacts from the seepage of tailings contact water. The need for water treatment may diminish over time after closure as the tailings dry and the seepage rate decreases. This may lead to an adaptive management approach, where the water treatment is continued after closure until it is no longer required to meet success criteria.

Another approach to controlling seepage from reactive tailings is the use of a cover to minimise or eliminate impacted contact water. There are a number of different types of covers, which have different modes of operation. The selection of the type of cover is strongly driven by climate, as illustrated in the figure below.

Submerging tailings under water (in-pit disposal) or flooding a tailings area to form a water cover for closure can both provide very effective limits on oxygen. When water covers are not viable, another potential control mechanism is to construct a 'dry' cover over the tailings, which could comprise a layer of non-reactive tailings, overburden or topsoil layers, or geosynthetic materials.

Dry covers can also limit the rate of infiltration and thereby reduce the volume of seepage/leachate from a mine waste facility. Dry covers may not completely stop either acid generation or infiltration. Consequently, closure planning needs to consider the need for ongoing monitoring of seepage to confirm that volumes and quality meet discharge criteria. It may also remain necessary to manage seepage for some time after closure.

The design of covers is a highly technical area. Closure plans that include the use of covers should contain details of the tailings geochemistry, cover material properties and analytical predictions of the cover performance. Refer to the GARD Guide for a discussion on cover selection and design.

Waste rock facilities closure

The closure of waste rock facilities needs to address a range of closure objectives. Closure activities for the objectives related to the guiding principles of both physical and chemical stability are discussed below.

8. Wickland, BE, Wilson, GW, Wijewickreme, D, and Klein, B (2006). 'Design and evaluation of mixtures of mine waste rock and tailings', *Canadian Geotechnical Journal*, 43:9, pp 928–45.

Design of closure activities for physical stability of waste rock facilities
Waste rock facilities are typically formed by dumping waste rock off the edge of a working bench. This dumped material will stand at an angle that is called 'angle of repose'. While this angle varies depending on the characteristics of the rock, it is typically too steep to practically place and retain soil – if a soil cover is needed either to control infiltration or promote rehabilitation and vegetation of the site, it will be necessary to flatten the slope. A slope of 18 degrees or even less is typically the limit, with 22.5 degrees considered the outer limit for effectively grading cover materials. This flattening can be facilitated by a process known as 'benching' during the placement of the waste. Several horizontal step backs are placed between each sloped area, such that the overall average slope will meet the closure objective. Appropriate stability criteria will need to be met for both the berms during operation and the flattened closure slope.

The overall stability of a waste rock facility is often governed by the strength of the soil foundation at the toe of the facility. Geotechnical investigation and design is required to provide an adequate factor of safety against an overall foundation failure, and to verify that the inputs and assumptions used in the calculation of the factor of safety are credible. Typically, events that are statistically rare ('long return period') are selected for design (ie loading from an earthquake). In the case of residual or reactive waste rock, the effects of rock weathering should also be considered. Waste rock facilities should be designed and constructed with closure in mind because it may be difficult or impossible to augment the stability of a waste rock facility after placement.

Runoff from waste rock facilities should be controlled to prevent possible erosion of the slopes and covers. A conventional approach for this is to construct erosion-protected channels (or 'chutes') to safely carry runoff down the side slopes to the toe. In this approach, the top of the waste rock facility and any remaining benches are graded to direct runoff into the chutes. Care is needed in developing these designs as there are many examples where these channels have been under-designed and failed due to storm water flows exceeding design capacities, or these systems being unable to cope with differential settlement of the underlying material. Alternatively, geomorphic design principles may be applied to develop a waste rock facility structure that is curvilinear and mimics natural terrain with convex and concave surfaces leading to dendritic drainage swales that are designed based on the characteristics of stable natural streams in the vicinity of the site. Practices around geomorphic design are evolving rapidly.

Design of closure activities for chemical stability of waste rock facilities
Waste rock can be a source of ARD/ML, and the risk of this must be evaluated and addressed from the earliest design stages. The GARD Guide addresses protocols for waste rock characterisation.

Water that infiltrates into the top and sides of a waste rock facility may eventually appear at one or more points on the toe of the facility, or infiltrate directly to underlying groundwater. At some sites, it is possible to design for collection of this toe seepage for monitoring and, if needed, treatment.

The rate of acid generation can be reduced by reducing the flux of oxygen and/or water to problematic waste rock. One approach is to preferentially place waste rock that is susceptible to acid rock drainage generation into the middle of the facility and encapsulate it with inert or alkaline waste rock. Another approach is to place a cover over the surface of the waste rock facility to reduce the oxygen and/or water flux into the pile.

Considerations for the design of covers on waste rock facilities are similar to those previously outlined for covers on tailings. An important difference is that steeper slopes are common on waste rock facilities and may require flattening to permit cover placement (which can be expensive), or the cover options available will be severely limited to approaches that are feasible on steep slopes.

Heap leach facilities closure

Heap leach facilities involve the irrigation of ore piles with solutions (acid or cyanide solutions are common) to dissolve the metals and carry them into a leachate collection system. Closure of heap leaches usually starts with allowing residual solutions to drain from the heap and processing them for as long as is economically viable. Closure plans should contain predictions of the drain-down time and chemistry as required.

In some cases, it may be desirable to 'flush' the heap leach to remove solution from the heap leach in a controlled way (typically for gold heaps). Experience shows that interactions are chemically complex, and general rules such as flushing with three pore volumes of water are inaccurate. Site-specific laboratory column tests are likely to give more defensible estimates. In other cases, it may be better to not flush the heap leach as it uses a significant amount of clean water and generates a substantial amount of impacted water that must then be managed.

Seepage collected from heap leaches may or may not require treatment for some period of time (dependent on the climate). The need for this requires evaluation on a site-specific basis, and in consideration of the site's overall water management approach. If treatment is needed, appropriate designs will need to be developed.

Slag and process residues closure

Slag can be in either of two forms: dumped slag, which physically resembles waste rock, and granulated slag, which is physically like coarse sand tailings. The design of stable physical containments for slag is similar to the design of stable waste rock facilities. Slag is crystallised material with a high content of iron silicates, which is usually not particularly prone to acid generation. A closure plan should still, however, contain a geochemical characterisation of the slag materials.

Process residues often contain substantial quantities of chemical precipitates such as gypsum that can considerably alter their geotechnical properties in comparison to conventional particulate tailings.

The chemistry of process residues can also vary widely, and they can contain relatively unstable oxides. Process residues need to be subject to careful geochemical characterisation.

Closure plans should include geotechnical properties, geochemical testing of the residue and predictions of the long-term physical and chemical stability, with risk assessments conducted if appropriate.

Mine infrastructure

Closure activities for mine infrastructure are relatively standardised. Transitioning from an operating site to a closed site typically involves a decommissioning process with the removal of infrastructure for a variety of reasons, including eliminating physical, chemical and electrical hazards associated with unauthorised access to buildings and preparing the land for transition to its post-closure use.

One of the most important challenges for managing the closure of infrastructure is ensuring that the sequence of activities is correctly planned. Power infrastructure, camps and maintenance facilities may all be needed for support of other closure activities. Depending on the sequencing, temporary camps and facilities may be needed to support the final period of closure activities.

For mine and processing infrastructure (buildings; power lines and pipelines; roads, ports and railways; concentrators, refineries and smelters), the typical sequence of closure activities is often as follows:

1. **Compile an inventory:** An asset register with all buildings and infrastructure will be needed for planning purposes. This list should include risks associated with each individual asset. A rigorous assessment of all hazardous substances is necessary to evaluate the need for decontamination, and to develop appropriate provisions. At the detailed design stage, surveys should be undertaken to capture all underground and redundant services and termination points. Design or as-built documents (eg structural drawings, equipment lists, material take-offs) will assist design and planning for decommissioning.
2. **Explore alternative uses:** Alternative uses for infrastructure should be explored, such that it can stay in place, with appropriate responsibility for operation and maintenance transferred to the regulatory authority, community or other third party. For example, roads, clinics and camps may be of interest for community use; wellfields may be attractive for agricultural or other industrial use; and

Dishaba mine infrastructure, South Africa airports may be of interest for regional use. Careful discussion and planning is required in transferring mining infrastructure as the receiving owner may not be in a position to safely operate the infrastructure, or have the capacity (technical skills, finances) to operate and maintain it safely and sustainably. Transfer of legal liabilities also requires documented agreements.

3. **Wind-down:** Inventory of assets such as mobile equipment, tools and consumable inventory in stores/ warehouses should be managed leading into closure, with inventories brought down to needed levels and excess material sold, recycled or disposed of.
4. **Isolation:** The first steps of decommissioning typically involve safely isolating utilities, including connections for power, water and gas. Prior to decontamination, fuels, oils or bulk chemicals should be removed from all storage vessels and purged from any service lines that run within the site, pumps, motors or the like.
5. **Decontamination:** Decontamination of structures and industrial equipment is required where hazardous substances have been used or equipment has been contaminated through the operational process. This may involve cleaning structures to remove undesirable residues; abatement of hazardous materials such as lead paints, asbestos or polychlorinated biphenyl-contaminated transformers; and clean-up of any other associated soil or water. This may occur before, during or after demolition and deconstruction activities.
6. **Demolition/deconstruction:** This is the process of physically taking apart infrastructure and may involve disassembly of some or all of the structures or destruction of infrastructure with heavy equipment or explosives. Modelling the cutting sequence and induced collapse of some of the more challenging and complex structures may also be undertaken to inform the safest and most effective demolition method.
7. **Salvage:** Typically, some portion of the demolished infrastructure will have economic salvage value. This material is separated during the demolition process and transported off-site for sale or reuse.
8. **Disposal:** Inert demolition waste is typically disposed of in a non-hazardous landfill, either off-site or on-site. This may require construction of new licensed landfills. It is also common practice to dispose of inert construction wastes (particularly concrete rubble) in on-site waste disposal facilities. This may require specific authorisations from regulatory authorities and planning to ensure that suitable capping material and the like is available. Where landfilling is required, quantities to be disposed of should be carefully estimated to ensure there is sufficient capacity. The decontamination process itself will likely generate a significant volume of liquid (wash-down water) and solid hazardous materials to be managed in accordance with waste handling and disposal requirements, such as secure on-site disposal, or to licensed landfills for solid and/or hazardous wastes. On-site water treatment may be necessary.
9. **Remediation:** During the operational phase, some soil or groundwater contamination may have occurred. If remediation was not done during the operational phase, it should be completed as part of closure. This will require assessment of the extent and nature of contamination, and related impacts, implementation remedial activities (such as landfarming or disposal of impacted soils in an authorised facility) and verification that remediation has been carried out to applicable standards. It is recommended to have a conceptual understanding of where contamination is likely to have occurred prior to the removal of infrastructure.
10. **Ground preparation:** Depending on the next land use, foundations may be left in place, covered or broken up. Compacted surface soils may be de-compacted and/or scarified. Direct revegetation may be possible, or soils placed in the areas of former infrastructure and revegetated.

Tool 11: Social investment for Closure

This tool is designed to foster collaboration for those involved in the development, allocation and delivery of a mine's social investment programme and/or a mine closure plan, such as:

- members of the operation's community, corporate affairs or sustainability team in charge of developing and implementing the social investment programme
- procurement/supply chain, government relations, human resources, mine planning and operational teams
- external stakeholders (government, NGOs and communities) who understand the considerations in devising a company's social investment programme, and therefore can identify and prepare for opportunities and their participation.

The table below provides a qualitative self-assessment questionnaire intended to prompt discussion between social investment planners and implementers. It comprises a series of questions that can be considered in their entirety or partially.

Social investment for closure self-assessment questionnaire

	Not at all/ unknown	Somewhat	Moderately	Significantly	Completely
How good an understanding of social transition issues is there?					
— To what extent is the currently available social baseline information adequate for helping understand social issues and social trends?					
— To what extent are the post-closure social impacts understood?					
— To what extent have the business risks of social transition been identified, including employee retention when the operation nears closure?					
— To what extent have different scenarios relating to social transition been developed?					
— To what extent can the predicted impacts and scenarios be relied upon as being accurate?					
— Have groups that may be particularly vulnerable to the impacts of closure been identified and the potential impacts on them understood?					

	Not at all/ unknown	Somewhat	Moderately	Significantly	Completely
To what extent is there a common shared vision of a post-mining future for the area?					
— To what extent is there a long-term vision and/or development plan for the area?					
— To what extent do different key stakeholders share and agree about this long-term vision or plan?					
— To what extent does this vision consider the social impacts of mine closure?					
— To what extent are other big trends or changes that can be foreseen understood and taken account of in this vision or plan?					
To what extent does the current approach to mine management integrate social transition issues?					
— To what extent has mine design incorporated social transition issues (eg shared infrastructure design)?					
— To what extent have social transition issues been considered and managed through operations (eg skills development, local supplier development, progressive land rehabilitation, etc)?					
— How fully have closure plans been developed?					
— To what extent does the current closure plan consider social issues?					
— To what extent have success criteria for social transition been defined?					
To what extent are there legal or other requirements that support social investment for closure?					
— To what extent are there legal requirements that are relevant to social investment for closure?					
— To what extent are there corporate or financing requirements that are relevant to social investment for closure?					
— To what extent has the company made specific commitments relating to social investment for closure?					
— To what extent are there wider societal expectations, norms or peer practices that may determine social investment for closure?					
How strong is the need for additional social investment to build socioeconomic resilience?					
— How soon is closure expected?					
— To what extent are the risks that mine closure may occur earlier than expected understood?					
— To what extent are the economies and livelihoods of affected communities dependent on the mine?					
— To what extent are there other economic or livelihood opportunities that could replace mining-reliant jobs?					

	Not at all/ unknown	Somewhat	Moderately	Significantly	Completely
— To what extent have post-closure impacts been designed out or progressively managed to minimise significant shocks during and beyond closure?					
— To what extent have financial provisions been made to finance investments to support social transition?					
— How clearly has the business case for social investment for closure been defined?					
To what extent does the site's current approach to social investment integrate social transition issues?					
— To what extent have the scope and boundaries of social investment for closure been defined?					
— To what extent has the site's social investment policy or procedure been developed?					
— To what extent has a comprehensive site social investment plan been developed?					
— To what extent do existing social investments consider long-term sustainability in terms of capacity for ongoing management and financing post-closure?					
— To what extent is the social investment plan aligned with the site closure plan?					
— To what extent is social investment focused on supporting priority areas to build social resilience?					
— To what extent does social investment support the following areas:					
– capacity building of local government for post-closure governance and service delivery?					
– capacity building of community groups and civil society organisations?					
– support to long-term development planning?					
– securing land and property rights?					
– skills development appropriate to post-closure skills demands?					
– business development appropriate to post-closure economy?					
– vulnerable and marginalised groups particularly at risk from post-closure impacts?					
– support to public infrastructure?					
– investments in land availability and use?					
— To what extent do the above areas align with anticipated social transition priorities?					
— To what extent is the social investment approach aligned with local long-term development plans and priorities?					
— To what extent is social investment for closure being progressively implemented?					

	Not at all/ unknown	Somewhat	Moderately	Significantly	Completely
To what extent are key stakeholders engaged in the social transition planning process?					
— To what extent have the different stakeholder groups related to mine closure been identified?					
— How well are the roles and responsibilities of different stakeholder groups in the closure process understood?					
— To what extent do key stakeholders understand the closure plan and objectives?					
— To what extent are communities open to discussion about social transition issues?					
— To what extent is the current relationship between the mine and stakeholders supportive of engagement on social transition issues?					
To what extent is there a coordinated and competent team responsible for managing social transition issues?					
— To what extent are senior management aware of the social impacts of closure?					
— To what extent are management committed to investing in managing social closure issues?					
— To what extent is the company willing and able to make investments in social issues for closure (eg what is the risk appetite, financial capacity, time horizon of management, etc)?					
— To what extent are departments other than those directly responsible for social performance/community relations supportive of social transition issues?					
— To what extent have roles and responsibilities been defined for social transition and social investment for closure?					
— To what extent has a central point been given the authority to lead and coordinate social investment for closure activities?					
— To what extent is there a defined and working team responsible for social investment for closure?					
— To what extent are there incentives relating to performance of management of social transition?					
— To what extent is there a clear budget and staff resources for social investment for closure?					
— To what extent is the mine clear about what skills and competencies are required to successfully manage social investment for closure?					
— To what extent does the mine team have these skills and competencies?					

	Not at all/ unknown	Somewhat	Moderately	Significantly	Completely
To what extent do other stakeholders have the capacity to govern and manage social transition issues?					
— To what extent are collaborative or partnership models being used in social investment for closure?					
— To what extent is there a detailed understanding of the capacity of the different stakeholders that are responsible for governing and managing social transition issues?					
— To what extent does local government have the capacity to govern and manage post-mining social transition issues?					
— To what extent do communities and community-based organisations have the capacity to govern and manage post-mining social transition issues?					
To what extent are there sustainable and effectively governed financial resources for social investment for closure?					
— To what extent is the scale of financial provisions for social investment in line with social impacts/risks and requirements/needs for social investment?					
— To what extent have provisions been made to guarantee ongoing social investment for closure independently from financial or operational performance of the site?					
— To what extent have dedicated financial mechanisms (eg trusts) been established to ensure independent management of social investment for closure?					
— To what extent have joint institutional arrangements (eg multi-stakeholder boards, advisory committees, forums, etc) been established to manage and hand over responsibility for some areas?					
— To what extent is there potential for other sources of complementary funding?					
— To what extent is there coordination with or leverage of other funding sources?					
To what extent is social investment for closure monitored and evaluated?					
— To what extent have outcomes, objectives, targets and indicators been set for social investment for closure?					
— To what extent is the performance of social investment for closure regularly monitored?					
— To what extent are improvements identified, implemented and tracked in response to monitoring and evaluation?					

Tool 12: Closure Plan Documentation

This tool provides a set of key considerations when developing and updating a mine closure plan specifically relating to the contents of the plan and frequency of updates, as well as documentation for final closure.

The closure planning process must be documented in a formal written plan accompanied by supporting documents. This plan will be regularly updated throughout the mining life cycle. Closure plans will vary in detail depending on the mine's evolution in the LoA, and may be classified as conceptual, preliminary, detailed or final.

Contents of a closure plan

The contents and organisation of the closure plan may be dictated or suggested by regulation in the jurisdiction or by corporate standards. In some cases, it may be necessary to have one plan developed specifically to address regulatory needs and another more extensive plan (or version of the plan) developed to address internal corporate needs.

While the exact contents of the plan will vary, almost all plans include sections to address these four concepts:

— **Context:** information describing the mine and the environment in which it is situated.

— **Vision:** a description of what the final state of the site will be at final closure, underpinned by more specific closure objectives.

— **Closure activities:** the core of the plan, describing what activities will be carried out to attain closure.

— **Post-closure:** one or more sections describing what will be carried out after closure, including monitoring, maintenance, and plans for post-closure land use and/or relinquishment.

Closure plans establish a defined basis for closure cost estimates, which are based on the costs for carrying out closure activities. The tables below summarise the recommended minimum closure plan contents and recommended additional closure plan contents for good practice.

Recommended minimum closure plan contents

Section	Content
Introduction	Summary of the content of the plan.
Environmental context	Description of the environment, including climate, geology, land use, surface water, groundwater, flora/fauna, air quality and archaeology. This typically refers to the baseline study, updated with information collected during the operational life of the mine. The description may include traditional knowledge where applicable and appropriate.
Socioeconomic context	Description of the socioeconomic environment, including populations and settlement patterns in the areas of influence, demographic data, land claims (including indigenous land claims and traditional land tenure), livelihoods and economy, natural resource use and cultural heritage. This typically refers to baseline studies, updated with information collected during the life of the mine.
Mine context	Description of the mine, in terms of current installations and the installations included in the LoM plan. The focus of this description is on the extent and composition of the mine installations, and not on their functional role.
Closure vision, post-closure land use and closure approach	An overview of the closure vision, guiding principles and planned post-closure land use. This should also include documentation of engagement that has been done in the development of the closure approach.
Stakeholder engagement	Documentation of all engagement conducted with stakeholders on the plan. This can include a register of the instances of engagement, as well as a summary of how engagement results were incorporated into the plan.
Risk and opportunity assessment	Results of the risk assessments, either as a chapter integrated to the structure of the closure plan or as an appendix that provides supporting documentation and justification for choices made in the plan.
Closure activities	Documents the closure activities that will be implemented as part of progressive or final closure, often organised by mine installation and domain. This includes plans or designs for the closure activities and may include explicit identification of the objectives or risks that the closure activities have been designed to address. It may also include lessons learned through progressive closure activities and how those have influenced the choice of final closure activity, trade-off studies conducted to evaluate alternative activities and indications of how climate change considerations were incorporated into design.
Success criteria and post-closure monitoring and maintenance	A description of the methods and duration of monitoring and maintenance activities to be carried out after implementation of the closure activities. Monitoring is typically described with reference to the applicable success criteria.
Cost estimate	An estimate of the cost of implementing closure. This may be a calculation of the financial assurance amount for regulatory documents or an estimate of accounting provisions or LoM estimates for internally oriented closure plans.

Recommended additional closure plan contents for good practice

Section	Content
Plain language summary	A plain language summary of the closure plan is good practice. This serves as both a non-technical executive summary and as an aid to engagement with stakeholders on the closure plan. It is good practice to translate this summary into local language(s) where needed to help communicate the plan to affected communities.
Regulatory framework/ commitments	A summary of the regulatory framework and commitments related to closure is useful to include in the closure plan. This provides a single location where the regulatory constraints acting on the closure plan can be summarised, including legally binding closure commitments made through the environmental impact assessment process, as well as a registry of those commitments made to external stakeholders.
Post-mine land use/relinquishment	When significant work has been done to define the post- mine land use or establish a clear pathway to relinquishment, it can be useful to have a section of the closure plan that documents this.
Data management	For internal use, it is good practice to have clear data management protocols, which include monitoring data, research studies and results, as-built information for completed progressive closure works, and stakeholder engagement records, and to document this in the closure plan. Closure plans may evolve over years or decades at a given site, and robust data management protocols are needed to minimise the loss of information through staff changes.
References	It is good practice to track all the literature cited within the plan, including scientific literature, guidelines, engineering designs, study reports and other supporting documentation generated for the closure plan.

Updating the plan

As is stressed throughout this guide, closure planning is an iterative process, and these iterations will be captured in progressive updates of the closure plan document.

The broad trajectory of closure plan evolution over the LoM is expected to be from conceptual to detailed as the mine progresses towards final closure and rehabilitation. However, the details of this progression will be site specific. Where significant progressive closure is undertaken, the aspects of the plan related to implementation of progressive closure will advance to detailed design earlier. For mines with short lives, closure designs will need to progress through the typical engineering design stages (such as conceptual, pre-feasibility, feasibility and detailed design) rapidly, whereas closure designs for mines with very long lives may remain at a conceptual level for many years.

Update frequency: There is no hard rule for the frequency of updating closure plans. Some jurisdictions mandate the frequency of updates, either directly or through permit conditions. Typical industry and regulatory practice is to update plans every three to five years, with additional updates when there are major changes in the mine plan. In many cases, companies will have their own internal LoM plans that are updated on an annual basis.

These required updates may be supplemented by annual external reporting to document ongoing information collection such as:

- reporting of results from ongoing progressive closure
- updates on closure plan optimisations and research
- documentation of ongoing stakeholder engagement.

Internally focused accounting requirements may also require more frequent updating of accounting provisions for closure – typically, accompanied by a report documenting what has changed from the previous estimate of the provision.

The following provides a list of typical questions to ask when updating the closure plan or to inform whether an update may be required.

Key questions to ask when updating the closure plan
Has the business plan changed (eg mining process, mine plan, scale or pace, different processing method, amended mine waste disposal strategy, LoM, mining area)?
Have new environmental risks been identified (eg ARD/other leachate or seepage, topsoil loss, cumulative impacts from surrounding development)?
Have new socioeconomic risks been identified (eg artisanal/illegal mining, social unrest)?
Have laws and regulations changed?
Have surrounding/local land use practices changed?
Has the rate of progressive closure been slower or faster than planned?
Have learnings from progressive closure resulted in changes to the plan?
Have unit rates or inputs such as fuel price significantly changed?
Have non-compliances or design changes occurred that indicate flaws in construction or operation (eg tailings dam leak, waste dump stability angles)?
Have climatic conditions changed beyond design predictions? For example, have storms occurred during the operating phase that will significantly revise the estimated design storms? (see also **Tool 7: Climate change and mine closure concerns**)
Have community structures, including population and demographics, and cultural considerations changed in terms of either current status or predictions?
Have environmental or socioeconomic impacts been greater or less than predicted during the impact assessment?
Have operating strategies' impact on closure design changed?
Have benchmarking studies provided new/different ideas that should be considered?
Have long-term risks been effectively mitigated by the closure options or designs?

Post-closure documentation

The final closure plan is typically generated at the end of mine operations. Additional documentation related to the implementation of the closure plan is usually needed during and following implementation of the final closure activities, whether they are completed progressively or at the end of the mine life.

Post-closure documentation is needed for:

- regulatory acceptance of the final closure
- as-built documentation
- summary of maintenance and inspections works
- monitoring reports with summaries of comparisons of monitoring results to success criteria.

The form this documentation takes will vary according to the needs of the jurisdiction and the mining company. In an ideal process, post-closure reports will document progress towards meeting success criteria, with a final closure or relinquishment report documenting the completion of the closure to the previously agreed criteria, in support of release of the financial assurance amount and/or relinquishment of the site.

Note that final closure and/or relinquishment may take place at different times for different parts of the site, such that multiple relinquishment reports may be generated as different areas are relinquished or different portions of the financial assurance are released. Closure reports may also be generated even when a formal relinquishment is not possible, in support of devolution of all or part of the financial assurance.

Educational facility at Waihi gold mine, New Zealand

Acknowledgements

The development of this publication would not have been possible without the input and support of the individuals below. ICMM gratefully acknowledges the following contributions:

Consulting team
This report was developed in two phases. ERM supported the initial phase of development under the guidance of Kylie Ashenbrenner and Scot Foster. Golder Associates supported the second phase in finalising the document for publication to which ICMM is indebted to Björn Weeks.

ICMM team
Dawn Brock led the process to develop this guide, with input and support from Nicky Black, Hannah Clayton, Roper Cleland, Aidan Davy, Duncan Roberts, and Hafren Williams. Sally Innis, Jessica Nicholls, and Emma Gagen contributed to the 2025 update to the guide.

Alice and Will Beaven (Positive2) and Nic Benton (ICMM) provided creative design support.

Special thank you
The ICMM Closure Working Group were key contributors to this document. The group provided direction, input and expert review to the guide. Working group members included:

Kim Ferguson (AngloGold Ashanti), Carl Grant (Anglo American), Claudio Andrade (Barrick), Joanne Heyes (BHP), Thomas Calhoun (Freeport-McMoRan), Antje Nieder (Glencore), Charlene Wrigley (Gold Fields), Dave Bucar, Chris Cormier (GoldCorp), Jon Crosbie, Donna Noonan (MMG), Klaus Eppinger, Thiess Lindsay (Newmont), Victoire Luquet de Saint Germain (Orano), Amiel Boullemant, Darren Sharp (Rio Tinto), Peter Waters (South32), Mark Freberg (Teck Resources).

Representatives of the ICMM Tailings-Closure subgroup provided valuable direction and input to the 2025 updates to the guide. They additionally included:

Matthew Cox (Alcoa), Joseph Chihota (AngloGold Ashanti), Allison Brown, Bassam El Husseini (Barrick), Rebecca Getty, Michal Kozikowski, Chad LePoudre (BHP), Magnus Bergknut (Boliden), Rene Orellana (Codelco), Tamara Johndrow (Freeport-McMoRan), Johan Boshoff, Nosimo Macatsha (Gold Fields), Paschoal Cataldi (Hydro), Rynhard Kok, Kristen Pouw (Newmont), Laila Burger, Fernanda Maluly Kemeid, Malcolm Talmage (Rio Tinto), Ross Cooper (Sibanye Stillwater),Lis Boczek, Matt Lord (South32), Björn Weeks (Teck), Breno Castilho (Vale).

An independent peer review team from SMI CSRM including Nick Bainton, Dr Jo-Anne Everingham, Dr Sarah Holcombe, Deanna Kemp, Anna Littleboy, Sarah Mackenzie, John Owen and Dr Vlado Vivoda.

Andrew Brown (independent consultant) and Matthew Bliss from the Intergovernmental Forum who provided helpful feedback on an advanced draft.

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Updated February 2025