CHAPTER 19

Rehabilitation and Closure

CHAPTER CONTENTS

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Rehabilitation and Closure

Mining is fundamentally a process of selection that has, and always will have, direct and indirect impacts on the environment.

The General Assembly of the United Nations (UN) established the World Commission on Environment and Development, chaired by former prime minister of Norway Gro Harlem Brundtland. In 1983, the 21-person multicultural commission commenced a wide-ranging investigation into many issues. In 1987, it completed its work and reported to the General Assembly. The report was also published in book form (UN World Commission on Environment and Development, 1987). This report can be considered as the starting point for general awareness of the concept of sustainable development, a concept endorsed by most of the world's mining industry. Subsequently, the UN held a Summit of Heads of Government (SHoG) in Rio de Janeiro in 1991 to address the issues raised in the report. One outcome of this SHoG was Agenda 21, a document that set out what needs to be achieved to attain sustainable development on a worldwide basis.

In 1999, the World Business Council for Sustainable Development (WBCSD) contracted the International Institute for Environment and Development (IIED) to identify the state of the mining industry in addressing Agenda 21. The IIED in turn created the Mining, Minerals and Sustainable Development (MMSD) Project to conduct a participatory analysis of how the mining industry could contribute to the global transition to sustainable development (MMSD Project, 2002). This project identified major challenges across the world, one of which was how environmental management in the mining and metals industry could be improved. This topic concentrated on three separate, but inter-related, aspects of the mining industry: closure, large volume waste and abandoned (legacy) mines.

Modern miners have recognised their role in striving for worldwide sustainable development. In particular, miners acknowledge the requirement to manage their operations in ways that minimise the unwanted and often unnecessary adverse environmental impacts of their industry.

The only certainty for any mining operation is that the operation will eventually close! To obtain and retain a social license to operate (SLTO), every mine needs to be closed in a manner that the community accepts.

PLANNING FOR CLOSURE

Mine closure is attracting increasing attention from governments around the world because of past practices that have left many legacy sites posing risks to the community. These sites will require very large sums of money to rectify them to modern environmental and safety standards. Governments around the world have recognised that the various surety systems they hoped would insure them from the cost of doing this remedial work have failed to provide the level of funding needed.

This recognition has resulted in stricter mine closure standards and funding transparency now being required of newly approved mining operations, together with a requirement for detailed closure planning and costing by existing mining operations. Selecting the final closure option at a site should involve consultation with all stakeholders (particularly governments) and an agreement on the closure objectives, so that company planners have clear, defined goals.

Closure planning process

Closure planning should begin during the early planning phase for any proposed mine and as soon as practicable in the mine life cycle for existing mines.

Figure 19.1 illustrates the closure planning process. This schematic shows that as the project progresses, more data become available, enabling more detailed closure planning and more accurate cost estimating to take place. Conversely, it also shows that decisions made early in the project life, such as where to locate the tailings storage facility (TSF), limit the closure options available to the planners later in the project life.

Companies need to clearly recognise both of these aspects of the closure planning process and should design the project from the outset with the final land use and other closure objectives as key design and planning considerations. This is the best mechanism to minimise the overall cost of the project.

Closure planning continually evolves and should be considered at all stages of the project's life, with revised cost estimates being undertaken to reflect this evolution in concepts and available data.

There are three broad stages in the closure planning process, shown in Figure 19.2, which form a continuum.

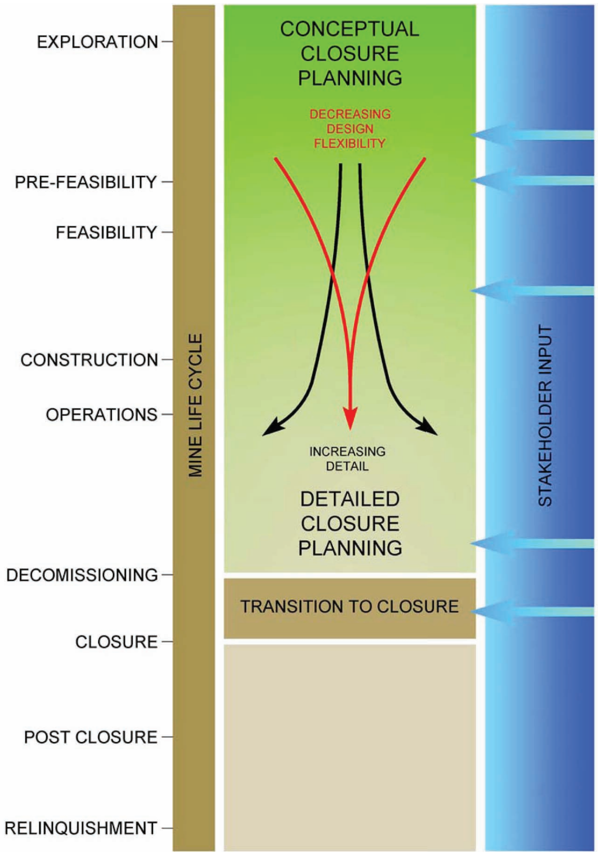

FIG 19.1 - Closure planning process (after International Council on Mining and Metals, 2008).

Conceptual closure plan

The preparation of a conceptual mine closure plan (CMCP) is the first stage of the closure planning process. The configuration of the new landforms created during the mine life and how they will function in the new post-mining environment should be addressed at this stage.

This stage typically involves extensive consultation with a wide range of stakeholders such as governments, shareholders, project neighbours and other potential land users.

The CMCP should identify and integrate the closure issues that will need to be addressed as early as possible in the project development process, often at the feasibility study stage. The conceptual plan is often costed to a nominal ±50 per cent accuracy, although experience suggests a cost overrun is common.

Operational closure plan

During operations, the CMCP should evolve into an operational closure plan (OCP) as a normal part of the mine operational planning process, so that the mine planners never lose sight of the final outcome of their plans and operations. This stage in closure cost estimating should be regularly reviewed using real cost data obtained from the operations, with accuracy in the range ±25 to 35 per cent being normal for the industry.

An important aspect of any plan is its effective implementation. This is considerably improved when the mine operations personnel are able to take ownership of the closure plan as part of their normal responsibilities. Ownership is best achieved by including operations personnel in the closure planning process.

Mine completion plan

This late stage of the project life mine completion plan (MCP) involves detailed engineering design of the agreed closure works, with costs estimated at ±10 to 15 per cent accuracy. Sometimes the MCP is renamed as the mine decommissioning plan at this stage to reflect that specialised contractors are often engaged for this final act.

Effectively decommissioning a mine is often as great a challenge as the original task of designing, building and commissioning the mine at the start of operations. In many practicable ways it is more challenging because many incidents and unplanned events affect many mining operations. All of these require investigation, and possibly remediation, before the mine site can be passed on to future owners.

RISK ASSESSMENT

Mine closure risk management involves the identification of factors that could potentially affect a

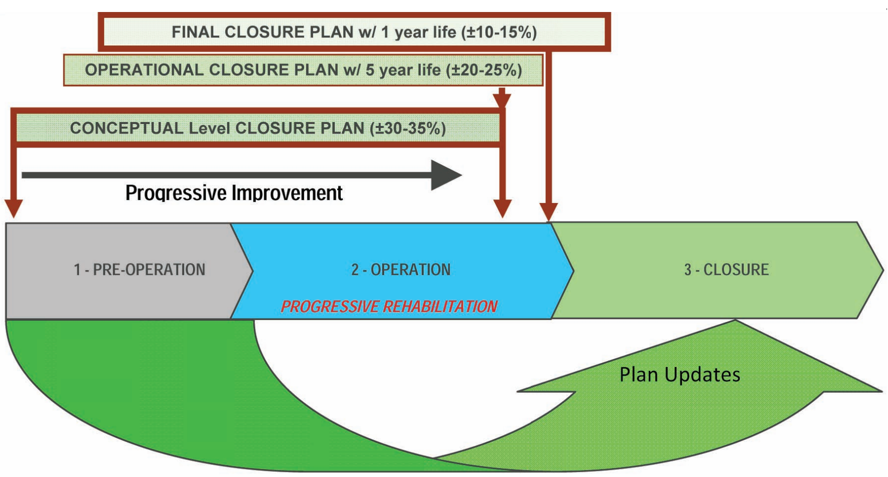

FIG 19.2 - Closure plan development.

mine site after operations have ceased and ensuring that control measures to eliminate or reduce risks that are considered unacceptable have been identified and implemented.

In Australia and New Zealand a generic framework exists for establishing the context, as well as for identifying, analysing, evaluating, treating, monitoring and communicating risk – this framework is the AS/NZS 31000-2009 *Risk management standard* (Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia, 2000).

Effective risk management seeks to ensure that:

- health, safety and well-being of employees and the public is not compromised
- environmental values are not unnecessarily affected
- financial performance of the business is protected
- the business earns its SLTO in the eyes of local communities, regulators and other stakeholders, based on performance.

People responsible for managing closure risks in the mining industry need to recognise the uncertainty and unpredictability inherently associated with natural processes to which mines are exposed at and after closure. The paucity of some key information may require the practical implementation of the 'Precautionary Principle', which was defined in the 1992 Rio Declaration on Environment and Development as:

> *Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*

AS/NZS 31000-2009 uses common methodologies for three levels of evaluating risks:

1. qualitative
2. semi-quantitative
3. quantitative.

During the preparation of the CMCP, a qualitative level of risk evaluation is typically carried out to identify and screen potential risks. Moving forward, the project will develop sufficient data for semi-quantitative and quantitative studies, as appropriate.

Potential risks considered in closure planning are those that may exist after the site has been successfully decommissioned and rehabilitated.

AS/NZS 31000-2009 adopts the traditional 'likelihood times consequence' model, but when applied to post-closure the likelihood has an extended time frame as post-closure extends over a very long time. The main factors likely to cause any consequences are the natural forces of erosion, deposition and ecological response to the changed (by mining) conditions. Some human intervention (salvage or artisanal mining) also causes unwanted consequences. In such a situation, the selection of time steps for the likelihood part of assessing risk functions is best if it is related to these natural processes, such as for the example shown in Table 19.1.

Note that the 'standard' engineering flood event for many fabricated structures with a return period of one in 100 years has a greater than 20 per cent probability of occurring in the next 25 years and is clearly not acceptable as a mine closure flood design.

CLOSURE COST ESTIMATES

Cost estimates are generated for mining operations at many stages of their life, commencing with the initial prefeasibility studies and continuing through to the final decommissioning cost estimates. The capital and operating cost estimates produced at various stages of the mine life are outlays intended to generate income and are readily assessed using a net present value (NPV) approach. Closure costs, on the other hand, are outlays that do not generate any income and do not easily fit into an NPV model, unless an interest-bearing closure fund is established. This has partly contributed to historically understating potential closure costs in many mining operations. Deloitte (2007) report that from 2000 to 2005 a survey of 27 mining companies showed an increase in cumulative tangible assets of those companies of 75 per cent, while the cumulative closure provisioning increased by 173 per cent (to $11.6 B) over that same period.

Not all closure cost estimates are the same. They will vary depending on the purpose they are prepared for, the organisation undertaking the estimate and the stage of the mining operation.

The different purposes of closure cost estimates include:

- complying with government requirements (eg Department of Mines and Petroleum and

TABLE 19.1
Potential likelihood descriptions – example.

Weather event	Return frequency	Likelihood description
Major climate change	1 in 10 000 years	Could happen on a geological time frame
Major flood event	1 in 1000 years	May occur only in exceptional circumstances
Two cyclones close together	1 in 25 years	Not impossible but could occur
One cyclone	1 in 10 years	Probable – may arise at least once in ten years
Heavy rain event	1 in 2 years	Very high

Environmental Protection Agency, 2011: Western Australian (WA) Mining Rehabilitation Fund legislation)
- government establishing potential liabilities (eg NSW Department of Primary Industries, 2006)
- meeting accounting standards (eg *Provisions, contingent liabilities and contingent assets*; AASB 137, undated)
- meeting stock exchange listing requirements (eg KPMG, 2004)
- project financial evaluation (eg due diligence and feasibility studies).

They can also be developed by different organisations such as:
- financial institutions
- operating companies
- state governments
- third parties (consultants).

These different organisations frequently arrive at different cost estimates for closing the same mine. This is because the organisations have different motivations for requiring the estimates and, therefore, different perspectives on how the estimates are managed. Financial Provisioning to meet AASB requires estimates for 'future obligations', while the most recent WA legislation requires estimates for current disturbance (Government of Western Australia, 2012). Another example is that governments often need to estimate the closure costs for many mining operations and so they will often use a pro forma, unit-rate approach such as the *Rehabilitation cost calculation tool* (NSW Department of Primary Industries, 2012). This will almost certainly give very different cost estimates from the site-specific estimates done by the operating companies and third parties.

Similarly, some estimates will be conducted on the basis of a third party undertaking the mine closure work (eg CICA 3110 requirements; KPMG, 2004), while an operating company's cost estimate would be based on the company doing the majority of the work as a continuation of their operations.

Another reason for cost estimate variations on the same site is the different definition of closure costs used by different estimators. For example, in some cases the closure cost estimate may include all progressive rehabilitation work carried out as part of the normal production operations at the mine; in other cases these activities are excluded from the closure cost estimate.

The *Leading practice sustainable development program for the mining industry* (Commonwealth of Australia, 2006a-c) includes a handbook entitled *Mine Closure and Completion*, which has been widely adopted by state governments.

The terms 'mine closure' and 'mine completion' are defined in this handbook as:

> *Mine closure is a process. It refers to the period of time when the operational stage of a mine is ending or has ended, and the final decommissioning and mine rehabilitation is being undertaken. Closure may be only temporary in some cases, or may lead into a program of care and maintenance. In this sense, the term mine closure encompasses a wide range of drivers, processes and outcomes.*
>
> *Mine completion is the goal of mine closure. A completed mine has reached a state where mining lease ownership can be relinquished and responsibility accepted by the next land user. To achieve this in an environment of increasing regulatory and stakeholder expectations requires that superior outcomes are developed and implemented in consultation with relevant stakeholders, including local communities.*

Using the above definition for mine closure would give a more consistent approach to mine closure cost estimates by different estimators. It would essentially include the costs incurred by the company after production has ceased and would largely exclude progressive rehabilitation from the closure cost estimate.

The remainder of this chapter uses this definition of mine closure in outlining the costs that should be incorporated into a mine closure estimate.

Salvage

Salvage values are not normally included in the closure cost estimate for two reasons. First, many accounting requirements for the mining industry do not allow the reduction in closure costs through the inclusion of salvage values. Second, the real value of any item disposed of can only be known on the day it is sold.

Rehabilitation of landforms

The development of new landforms such as waste dumps, tailings facilities and mine infrastructure is an inevitable outcome of most mines. At closure these landforms will usually need to be reconfigured and probably vegetated before the site can be relinquished.

The landforms will usually need to be landscaped to their final design configuration, a shape that should be designed to withstand the maximum credible earthquake (MCE) for that site. This final shaping will include the construction of a robust drainage system, preferably designed to accommodate the probable maximum flood (PMF) event for the site. Part of the water management on the landforms may include the construction of 'store and release' capping.

The shape of the landforms will determine their susceptibility to erosion and the potential development of gullies (McPhail and Dye, 2008). This is particularly important when potential contaminants such as sulfide minerals or other problematic materials are contained within the structures, as development of deep gullies can release pollutants, which may require ongoing treatment over a considerable period.

It should be noted that the expected design life for the completed landforms is measured in centuries and not decades. Failure to design and construct suitable landforms could result in a failure to relinquish the site at closure, with ongoing maintenance outlays after operations cease.

Establishing vegetation on the created landforms is often a government requirement. In the early stages of mining, on-site trials can be used for developing cost estimates, while in the latter stages of most mines actual progressive rehabilitation costs could be used. Where no site-specific data are available, cost estimates could be sourced from suitably qualified contractors.

When mine closure plans exist, development of the final landform design can considerably reduce closure costs by allowing the wastes to be placed directly in their final locations. This reduces, to a practicable minimum, costly double-handing to attain the required final landform.

The stages of developing the final waste dump landform can be roughly grouped as shown below. Not all of these activities will be required at each site, but all stages should be considered. For closure cost estimating purposes these stages can be broken down as:

- general configuration
  - design of landform
  - dozing and other earth works (load-haul-dump) to meet design requirements
- final drainage development
  - development of defined catchments
  - profiling of drainage routes
  - lining of drainage routes with suitable bed material (usually sized, competent rock)
- conditioning of growth media
  - chemical and fertility laboratory assessments of available growth materials (macro and micro chemistry)
  - addition of required chemicals
- growth media placement
  - salvage of growth medium (stockpile top soil, oxide waste, or material from borrow areas)
  - recovery from stockpiles
  - placement at required thickness
  - physical conditioning (deep ripping, etc)
- seeding
  - collection of suitable seeds (usually endemic species)
  - spreading of seed
- monitoring
  - regular monitoring of rehabilitated and analogue areas
  - comparison with predicted trends
  - continuation until completion criteria are met (several years)
- maintenance
  - exclusion of feral animals (fences, etc)
  - repair to damaged areas (earth works)
  - growth media enhancement, and reseeding of underperforming areas.

Where the final landform is a TSF most of the above landform and vegetation establishment aspects will apply together, with several additional activities. These may include, but may not be limited to:

- capping of upper surface
  - access, which may be considerably delayed by the tailings condition
  - sourcing of suitable materials
- construction of diversion structures around the TSF
  - spillways constructed to manage PMF
  - decommissioning of under-drains
- decommissioning of decant system
  - removal of pumps and power supply
  - removal of tailings and return-water pipe lines
  - sealing off if the system is a gravity decant
  - filling in of any decant ponds
- embankment reconfiguration (removal of terraces) (McPhail and Rye, 2008)
- embankment armouring, particularly if the upstream construction technique was adopted
- maintenance
- monitoring of groundwater levels and quality (probably for several years).

Costs for all of the above should be developed from the most recent mine closure plan. Site-specific unit costs should be used when these are available, or alternatively quotes from suitably qualified specialist contractors should be used. It is also possible to construct cost estimates based on known equipment performance and operating costs.

An important aspect of estimating final closure costs is the potential for ongoing pollution after closure. This often takes the form of acid and metalliferous drainage (AMD) resulting from the incorporation of sulfide and other minerals in the waste landforms. Thorough assessment of the geochemical characteristics of all mine wastes should identify any potential pollutants, enabling mitigating strategies to be developed and costed. A problem with AMD is that it often only becomes evident after mine closure, with the result that significant remedial actions are required to minimise the resulting pollution. In operations where the potential for AMD exists, estimators should err on the side of caution by requiring assurance that the constructed landforms have been designed to reduce this pollution potential to a practicable minimum.

A recent publication (International Council on Mining and Metals, 2012) indicates that the post-closure part of the mining life cycle is normally expected to last at least one decade in many operations, and considerably longer (in perpetuity) in some cases.

Process plant

Most mining leases have conditions on them that require companies to remove all plant and equipment from the site after operations cease, unless a recognised third party is prepared to take on the responsibility for that plant and equipment.

It is typical for the decommissioning, deconstruction and removal of process plants to be conducted by specialist contractors. Because plants vary considerably in their configurations and complexity, the real removal costs reflect this reality. Several process operations, such as cyanide gold operations and uranium operations, also require special considerations for the potential toxic residues and community perceptions.

The cost estimate applicable to the process plant, equipment, infrastructure and built facilities normally covers decommissioning, dismantling and demolition only. It does not include the cost for removal of scrap from the site, as it is normally assumed that the scrap purchaser bears this cost. Similarly, should any equipment be sold to a third party (eg ball mills), that third party is assumed to incur the cost of removing that equipment from site. The balance of material remaining at the site, that either cannot be re-used or is uneconomic to re-use, is normally disposed of in accordance with the applicable legislative requirements (often aimed at a 'zero harm' standard). This includes:

- use of appropriate removal and sorting procedures
  - waste classification
  - compliance with waste disposal legislation
- use of registered, licensed carriers
- selection of appropriate disposal techniques
  - burial in suitably designed solid waste landfills
  - destruction
- tracking of volumes and materials to their final repository
  - hazardous material repositories (often state-managed)
  - chain of custody
- construction of suitable repositories at identified locations.

Some major concrete structures will almost certainly remain on-site at closure, such as the foundations for the crusher, but most of the other materials that cannot be transported from site will be buried in a designated waste disposal facility. The materials are normally separated to waste classes. Different classes are placed in separate facilities, some of which may require an engineered liner and impervious caps. Construction of suitable repositories will depend on the materials to be disposed of, the location and local legislation.

A typical checklist for process plants includes:

- concentrate recovery
  - drying facilities
  - filters
  - product handling sheds
- grinding
  - mills
  - pumping systems
  - screens
  - transfer conveyors
- ore preparation plant
  - bins
  - blending stockpiles
  - conveyor belts
  - crusher(s)
  - screens
- product recovery
  - elution equipment
  - goldroom
  - leach tanks
  - reagent handling equipment
- pyrometallurgy
  - exhaust stack
  - fuel supply equipment
  - fuel tanks
  - roasting equipment
  - smelting equipment
- waste management
  - scat disposal
  - tailings pipe lines
  - thickeners
- wet process
  - concentration systems
  - flotation cells
  - leach tanks
  - reagent handling
  - tanks.

If the operation is a cyanide gold operation then the closure cost estimate should consider the closure procedures recommended in the *International Cyanide Management Code* (International Cyanide Management Institute, 2006).

Mobile equipment

Closure cost estimates normally assume that all mobile equipment at the operation will be sold or otherwise transferred to third parties, where the third party is responsible for the removal of the mobile equipment from the mine site at no cost to the operating company. Equipment that cannot be passed on to third parties will need to be disposed of, along with other scrap materials, and may need to be buried at a suitable facility.

There are some exceptions to this, such as in uranium mining operations, where the equipment in question has been potentially contaminated during its operating life and cannot be decontaminated to a level that will enable it to be reused. In these cases the cost estimate must allow for the suitable disposal of that equipment.

Open pits

Regulatory authorities normally require open pits to be left in a 'safe and stable condition'. In some cases the open pit is simply left as a large excavation that may or may not partly fill with water over time. In other cases the open pit may have been used as a repository for tailings or mine waste and may be partly or completely filled with those materials. Where a pit has been used as a repository for mined waste there may be a requirement to establish vegetation on that waste.

In all of these cases there will normally be a requirement to limit inadvertent public access and, in some jurisdictions, provide ready egress for recreational users (authorised or otherwise) and safe access for emergency services should members of the public suffer an accident.

During mining, the pit walls will have been designed to remain standing for the duration of the operation, but normally little consideration is given to the long-term, post-mining stability of the excavation. Following closure, many open pits experience 'fretting' at the pit rim and the location of any inadvertent public access limitation system will need it to be sufficiently far back from the pit rim to allow such fretting without compromising the public limitation system. This will preferably be a rock bund 2 m or more high (Department of Industry and Resources Western Australia, 1997).

Allowance needs to be made for geotechnical investigations to determine the optimum location (the 'safe line') for the limitation system.

A typical checklist for an open pit could include:

- emergency services access
- geotechnical investigations to locate public access limitation systems
- monitoring of groundwater response (several years)
  - development of suitable groundwater response model
- monitoring of water quality in open pit
- public access limitation system
  - development
  - construction
  - maintenance
- removal of explosives magazine
- removal of fuel farm and clean-up of any hydrocarbon-contaminated areas
- removal of mobile equipment workshop
- rehabilitation of access roads to the open pit
  - conditioning of growth media
  - drainage
  - growth media placement
  - seeding
  - monitoring and maintenance
- safe disposal of remaining fuel and explosives.

Underground operations

Many jurisdictions have specific requirements for leaving underground access in a condition that the authorities deem to be safe. This normally includes:

- recovery of all equipment from underground, to the extent practicable
- sealing of all underground access
  - day-lighting stopes
  - drill holes that intersect the workings
  - haulage shafts
  - raise boreholes
  - ventilation shafts
- removal of all surface equipment
  - change rooms
  - ventilation equipment
  - winding systems
- monitoring of groundwater response (quality and levels) for several years.

In many cases, the respective mining regulations may require the company to investigate the potential for post-mining subsidence and could also require activities to reduce this possibility to the lowest practicable potential by backfilling some parts of the mine.

Infrastructure

Many mining operations are located in remote areas, with the result that the mines construct stand-alone infrastructure to provide process and domestic water supplies, power generation systems, workforce accommodation, emergency medical systems, road and air access and sometimes port facilities. Tenement conditions often require all of these structures to be removed from site. The procedure is similar to that for the process plant, with some equipment being sold, some removed from the site as scrap and some disposed of in suitable waste facilities located at the site.

The list of infrastructure will vary considerably from site to site, but will often include:

- access roads
- accommodation units
- airport or airstrip
- communication facilities
- domestic waste facilities
- domestic water supply
- medical centre
- offices
- power distribution system
- recreational facilities
- sediment traps
- sewerage system
- water treatment facility.

A contaminated site investigation would need to be conducted at all of the above locations to identify any areas polluted by chemicals or hydrocarbons, and any areas detected during the survey would require remediation. The requirements for these activities will vary from jurisdiction to jurisdiction, but all closure cost estimates should allow for at least a general contaminated site survey (sampling on a grid with laboratory testing of collected samples). More detailed investigations should be allowed for where there are reasonable grounds to expect chemical or hydrocarbon spills may have occurred. Allowance should also be made for the remediation of at least one area of contamination, unless the contamination survey indicated the site is clear of significant contamination.

The areas disturbed during the operations should then be ripped and seeded with endemic flora species in a similar manner to the rehabilitation of the access roads for the open pit. This means that costs need to be estimated for:

- drainage
- conditioning of growth media
- growth media placement
- seeding
- monitoring and maintenance.

Pollution monitoring and control

The successful closure (completion) of any mining operation will need to be confirmed by monitoring the environment for a significant period after all closure activities have been undertaken, rehabilitation has been completed and all built facilities have either been removed from site, or buried in a suitable facility.

It is normal for specific completion criteria to have been developed and agreed to by all stakeholders. In this context, a major purpose of monitoring is to determine when the criteria have been attained, allowing the property to be relinquished for use by others.

Chemical considerations

The chemical and mineralogical composition of the rock and earth disturbed during the mining operation will result in the release of soluble chemicals, a process usually referred to as AMD. This phenomenon often does not reach its peak until some time after the operating mine has closed. In many cases, it may be necessary for surface and groundwater to be monitored for an extended period, at least until the release of chemicals has stabilised. Similarly, the release of sediments into the environment will need to be monitored until an acceptable rate of release has been attained.

Where the potential pollutants stabilise at a level above that acceptable to the regulatory authorities, treatment of pollutant streams may be required for a considerable period. This can only be addressed and the cost estimated when a detailed evaluation of the pollution potential at the site has been undertaken.

Ecological considerations

The monitoring of rehabilitation areas is often conducted using an environmental function analysis, which compares the mine site ecological performance with previously selected analogue areas. This may require monitoring to be continued for several years, depending on the location, climate and agreed completion criteria. For estimating purposes, it is best to assume a minimum of five years post-closure monitoring will be required.

BONDS AND FINANCIAL ASSURANCE

It is important to differentiate between the terms 'surety' and 'financial assurance' as these terms are used in an almost interchangeable way in many different publications. In this chapter, the terms are defined as given below.

- surety – money that is made available to government to complete an environmentally acceptable mine closure after the mining company has failed to conduct the work required
- financial assurance – funds available within the mining company that enable the company to conduct those necessary works.

A wide range of different surety and financial assurance mechanisms can be used by government and mining companies to make sure suitable funding is available to manage closure. They have a wide range of different names and titles, some 16 of which are discussed in Miller (2005). The reader needing more detail is referred to that publication.

The five most commonly mentioned surety options are cash deposits, bank guarantees or letters of credit, trust funds, accounting reserves and insurance policies. A new surety option of a fund created by an annual levy (tax) is being introduced in Western Australia (Government of Western Australia, 2012). Each option has its positives and negatives when viewed from the perspective of the various stakeholders.

Cash deposits

Cash deposits are a considerable impost on a company's finance as they are a direct drawdown on the company's financial resources. They give the community and non-government organisations an apparent assurance that the funding is, and will always be, available if required. However, in some jurisdictions the ability of government to quarantine such a specific cash deposit from all of the government's other financial operations is frequently imperfect. This can result in funds being used well ahead of mine closure to address other government concerns. Ideally, the cash should not only be quarantined but deposited in a conservative interest-bearing vehicle, so that interest earned could at least partially counter the effects of inflation.

It should also be noted that in some countries if the mining company becomes bankrupt the cash the company has deposited with a government may be recovered by the receiver. This is a significant risk when more than one level of government is involved. This is the case in Australia, where laws often give one level of government (eg Australian Taxation Office) a higher standing than another (state mining or environment departments) when it comes to accessing the funds through a receiver.

Bank guarantees, letters of credit and bonds

Bank guarantees, letters of credit, bonds and similar instruments are provided by a third-party financial institution not related to the mining company or the government. They have the advantage to companies of not normally requiring all hard cash up-front, although this does depend on the rating the financial institution issuing the letter of credit or guarantee gives to the company. Such instruments have a direct impact on the credit available to the mining company because the company's available credit has been reduced by the amount of the guarantee or letter of credit. There is also a fee charged for this service.

These financial instruments provide government with a high degree of security, probably a higher degree than cash deposits as the likelihood of the third party going bankrupt at the same time as the mining company is very remote. Additionally, such devices avoid the need to quarantine the money within government. It also assures third-party stakeholders in the mine closure that the funds will be used for the specific purpose of rehabilitation at the end of mining operations. The amount of the letter of credit (or bond) should be adjusted over time to reflect changes in closure cost estimates and inflation.

These funds are only called on when a company has failed to meet the closure requirements, a process that can often take many years to legally establish.

Mining Rehabilitation Fund

Legislation assented to by the Governor of Western Australia in November 2012 will establish a Mining Rehabilitation Fund (MRF) to provide money for the rehabilitation of mines declared abandoned by the CEO of the department responsible for administrating the legislation. The MRF will be funded by an annual Mining Rehabilitation Levy imposed on all companies holding tenements under the *Mining Act 1978*, calculated on the Rehabilitation Liability Estimate (RLE) of the disturbance on that tenement. The rate of the levy, various categories of land to be included in the RLE, their respective nominal costs and other administrative details will be defined in the regulations, which are not available at this time of drafting.

There will be two categories of MRF money. The principle, which will be used to fund rehabilitation of abandoned sites in relation to which the levy has, or should have been, paid and the interest earned by the MRF, which will be used for administration and rehabilitation of other sites to which the levy obligation has not applied (legacy and orphan sites, etc).

Trust funds

Trust funds are generally financed by the mining company progressively investing more money in the fund as the operation develops. Therefore, these devices have a somewhat lower direct impact on the company's financial position than many other devices. The company then draws on the funds to conduct all its closure activities, including those that are progressively conducted throughout the mine life. However, this mechanism does require the establishment of a trust fund with suitable trustees. While some have been quite successful, others have apparently become bogged down in the legalities of operating a sole-purpose trust fund. Governments would normally require to be represented in the system.

Accounting reserves

These include balance sheet tests, accounting or financial reserves, corporate guarantees and other similar methods of demonstrating financial soundness and an ability to meet closure liabilities. Accounting reserves are used within a company as a financial assurance, but some governments also use them either as a substitute for direct surety, or as a means of reduced surety for companies that governments consider to be sound environmental risks.

Insurance policies

Insurance policies have an initial attraction to government as a method of obtaining funds to complete mine closure when a company has failed. However, insurance policies are only paid out when the premiums are up-to-date. Generally speaking, when mining companies default on conducting their post-mining environmental management and rehabilitation, it is because they have run out of funding and are, therefore, unable to meet the premium payments.

SOCIAL AND COMMUNITY CONCERNS

The social and community aspects of mine closure vary considerably from operation to operation. One factor is the loss of jobs that inevitably happens when mines close, but even this fundamental change in the social network around an operation will depend on the location of the mine, the source of its workforce, alternative employment opportunities and so on.

From a cost estimating perspective the factors to be considered include:

- redundancy payments
    - employment conditions
    - contract terminations
    - service agreement contacts (eg power and water supply to nearby communities)
- funding to relocate workers to other jobs
    - placement of apprentices

  - retraining of staff
- relocation of workforce from site
- handover of facilities to local authorities
  - transfer of assets
  - training of local authority staff
  - length of handover period.

EXAMPLES

The following hypothetical examples have been developed, based on several closure cost estimates the author has developed for particular mining operations. The examples are presented as a series of estimates for the same operation, done using different approaches to fit the requirements of the organisation commissioning the estimate and the stage in the mining operation the estimate was developed.

The Western Australian example is briefly described as a gold operation comprising two open pits near the process plant. The mine is located close to a river system that flows all year round and uses a TSF located in a side stream that has a very small upstream catchment. The climate results in about 1.5 m of rain per annum, concentrated in a four-month period. The mine has a planned life of 15 years and a production rate of 2 Mt/a of ore, a stripping ratio of 4:1 and is operated as a fly-in, fly-out (FIFO) operation.

At the feasibility stage (conceptual closure plan) a closure cost estimate could be as shown in Table 19.2.

After gaining approval to operate and having some environmental conditions placed on the operation, in particular a condition relating to potential pollution at the TSF, the operating company was taken over by a Canadian company. At the third year of operation the company was, therefore, required to prepare an asset retirement obligation estimate that assumes the operation will cease at the end of that financial year, and that all work would be undertaken by a third-party contractor.

At this stage the waste dumps had been partly developed, but no progressive rehabilitation has been possible while the slurry being deposited in the TSF had not reached design density, resulting in considerable excess supernatant water on the TSF. Quotes were obtained from contractors for the removal of the process plant and infrastructure. The resulting estimate would be similar to that in Table 19.3.

TABLE 19.2
Feasibility study closure cost estimate.

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Tailings storage facility	Capping and shaping of upper surface (average 1 m thick for 42 ha) as m^3	420 000	10	4 200 000
	Soil treatment and amelioration per ha	42	15 000	630 000
	Seeding per hectare	42	3000	126 000
	Construction of spillway per m^3	7500	40	300 000
	Mobilisation and demobilisation	1	30 000	30 000
	Removal of slurry and return lines per km	4	5000	20 000
Open pits	Geotechnical investigations per study	2	30 000	60 000
	Build safety bund-high walls only (5 m base by 2 m high) per linear metre, 1800 m total length (m^3)	9000	40	360 000
Waste dumps	Reshape per m^3	75 000	15	1 125 000
	Soil treatment and amelioration per ha	116	15 000	1 740 000
	Seeding per ha	116	3000	348 000
	Maintenance (ten per cent of area over five years)	11.6	5000	58 000
Process plant	Crusher circuit unit	1	300 000	300 000
	Carbon-in-pulp plant unit	1	1 150 000	1 150 000
	Workshops unit	1	50 000	50 000
	Plant and mine office unit	1	50 000	50 000
	Rehabilitate footprint per ha	15	8000	120 000
Conveyor belt	Remove per m	620	75	46 500
Remove built infrastructure	Deconstruction and removal (18 buildings)	18	12 500	225 000
	Rehabilitate footprint per ha	3	8000	24 000

TABLE 19.2 CONT ...

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Roads	Access road (8 m nominal width) – ripping per ha	16	5000	80 000
	Seeding per ha	16	3000	48 000
	Mine roads (15 m nominal width) – ripping per ha	6	8000	48 000
	Seeding per ha	6	3000	18 000
Airstrip	Ripping per ha	15	5000	75 000
	Seeding per ha	15	3000	45 000
Other disturbed areas	Seeding	6	3000	18 000
	Ripping, etc	6	5000	30 000
Water supply	Pumps and bores per unit	12	8000	96 000
	Holding tanks per unit	5	20 000	100 000
	Water supply pipe work per km	2	5000	10 000
Contaminated land	Survey	1	100 000	100 000
	Remediation per event	1	50 000	50 000
Monitoring	Rehabilitation – EFA for five years, per visit	5	75 000	375 000
	Surface water and groundwater monitoring per annum	15	120 000	1 800 000
Power supply	Powerplant removal (engines)	7	15 000	105 000
	Pole or line removal per km	20	4000	80 000
Subtotal				14 040 500
Project management	12% of subtotal			16 848 60
Total estimate				15 725 360

TABLE 19.3

Asset retirement obligation estimate for closure on 31 December 2016.

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Tailing storage facility	Pumping of water	420	690	289 800
	Treatment of supernatant water	420	200	84 000
	Capping and shaping of upper surface (average 3 m for 62 ha) as m^3	1 860 000	7.50	13 950 000
	Soil treatment and amelioration per ha	62	15 000	930 000
	Seeding per ha	62	3000	186 000
	Construction of spillway per m^3	7500	40	300 000
	Mobilisation and demobilisation	1	30 000	30 000
	Removal of slurry and return lines per km	4	5000	20 000
Open pits	Geotechnical investigations per study	2	30 000	60 000
	Build safety bund-high walls only (4 m base by 2 m high) per linear metre	2800	80	224 000
Waste dumps	Reshape per m^3	110 000	15	1 650 000
	Soil treatment and amelioration, per ha	56	15 000	840 000
	Seeding per ha	56	3000	168 000
	Maintenance – ten per cent of area over five years	5.6	5000	28 000

TABLE 19.3 CONT ...

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Remove process plant	Crusher circuit unit	1	282 000	282 000
	Carbon-in-pulp plant unit	1	948 000	948 000
	Workshop unit	1	68 000	68 000
	Plant and mine office unit	1	91 000	91 000
	Rehabilitate footprint per ha	15	8000	120 000
Conveyor belt	Remove per m	620	75	46 500
Remove built infrastructure	Deconstruction and removal (18 buildings)	1	150 000	150 000
	Rehabilitate footprint per ha	3	8000	24 000
	Waste disposal facility per ha	2	150 000	300 000
Roads	Access road (8 m nominal width) – ripping per ha	16	5000	80 000
	Seeding per ha	16	3000	48 000
	Mine roads (15 m nominal width) – ripping per ha	6	8000	48 000
	Seeding per ha	6	3000	18 000
Airstrip	Ripping per ha	15	5000	75 000
	Seeding per ha	15	3000	45 000
Other disturbed areas	Seeding per ha	6	3000	18 000
	Ripping, etc	6	5000	30 000
Water supply	Pumps and bores per unit	12	8000	96 000
	Holding tanks per unit	5	20 000	100 000
	Water supply pipe work per km	2	5000	10 000
Contaminated land	Survey per event	1	100 000	100 000
	Remediation per event	1	50 000	50 000
Monitoring	Rehabilitation EFA for five years, per visit	5	75 000	375 000
	Surface water and groundwater monitoring per annum	15	120 000	1 800 000
Power station	Powerplant removal (engines)	7	15 000	105 000
Power reticulation	Pole and line removal per km	20	4000	80 000
Subtotal				23 867 300
Project management	12% of subtotal			2 864 076
Estimate				26 731 376
Third-party mark up	15% of total			4 009 706
Overall cost				30 741 082

Note: EFA = Ecosystem Function Analysis.

The company's nominated date for undertaking an initial RLE is also 31 December 2016. This estimate would be done as described in the (yet to be published) WA regulations, but based on the assented MRF bill and supporting memoranda the estimate will be similar to that shown in Table 19.4. Based on this RLE, a Mining Rehabilitation Levy would be paid to the WA Government.

In subsequent years, the RLE would vary depending on the progressive rehabilitation the company has completed to the regulator's standards and the newly disturbed areas.

Note that this estimate is based on the area disturbed and the degree of rehabilitation potentially required, with the different categories of disturbance incurring different rehabilitation rates.

TABLE 19.4
Rehabilitation liability estimate.

Name	Description	Quantity	Unit Cost (A$)	Cost estimate (A$)
Tailings storage facility	Disturbance Type A: Category 1 TSF, more than 15 m high (per ha)	62	100 000	6 200 000
Open pits	Disturbance Types C: General category (per ha)	24	30 000	720 000
Waste dumps	Distrubance Type A: Category 1 (highly erodable soils) (per ha)	42	100 000	4 200 000
Process plant	Distrubance Type B: General category (per ha)	15	60 000	900 000
Infrastructure	Distrubance Type B: General category (per ha)	3	60 000	180 000
Roads	Disturbance Type C: Haul roads (per ha)	6	30 000	180 000
	Disturbance Type D: Access road (per ha)	16	18 000	288 000
	Disturbance Type C: Sewage ponds, landfill, etc (per ha)	6	30 000	180 000
Airstrip	Disturbance Type D: Airstrip (per ha)	15	18 000	270 000
Total estimate		189		13 118 000

In the last year of operations a decommissioning plan (mine closure plan) was prepared using actual operating data for costing rehabilitation, using contractor estimates for infrastructure and process plant removal and based on the actual areas of the total site that would still require rehabilitation after operations cease. This estimate would be similar to that shown in Table 19.5.

It is evident from these three hypothetical closure cost estimates for a single mine that the closure cost estimate depends on the time it is made, the available data on which to base the estimate and the purpose of that estimate.

In all cases the assumptions used to prepare the estimate need to be clearly defined, so that people or organisations using the estimate understand its limitations.

TABLE 19.5
Decommissioning closure cost estimate.

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Tailings storage facility	Pumping of water per ML	150	720	108 000
	Treatment of supernatant water per ML	150	140	21 000
	Capping and shaping of upper surface (average 1 m for 62 ha) as m^3	620 000	4.50	2 790 000
	Soil treatment and amelioration per ha	62	12 500	775 000
	Seeding per ha	62	1000	62 000
	Construction of spillway per m^3	7500	40	300 000
	Removal of slurry and return lines per km	4	5000	20 000
Open pits	Geotechnical investigations per study	1	20 000	20 000
	Build safety bund-high walls only (4 m base by 2 m high) per linear metre – 2750 m	13 750	35	481 250
Waste dumps	Reshape per m^3	110 000	11	1 210 000
	Soil treatment and amelioration per ha	34	12 500	425 000
	Seeding per ha	34	1000	34 000
	Maintenance (ten per cent of total area over five years)	11.6	5000	58 000
Remove process plant	Crusher circuit unit	1	282 000	282 000
	Carbon-in-pulp plant unit	1	948 000	948 000
	Workshops unit	1	68 000	68 000
	Plant and mine office unit	1	91 000	91 000
	Rehabilitate footprint per ha	15	8000	120 000

TABLE 19.5 CONT ...

Name	Description	Quantity	Unit cost (A$)	Cost estimate (A$)
Conveyor belt	Remove per m	620	75	46 500
Remove built infrastructure	Deconstruction and removal (18 buildings)	1	110 000	110 000
	Rehabilitate footprint per ha	3	6500	19 500
Roads	Access road (8 m nominal width) – ripping per ha	16	5000	80 000
	Seeding per ha	16	3000	48 000
	Mine roads (15 m nominal width) – ripping per ha	6	8000	48 000
	Seeding per ha	6	3000	18 000
Airstrip	Ripping per ha	15	5000	75 000
	Seeding per ha	15	3000	45 000
Other disturbed areas	Seeding	6	3000	18 000
	Ripping, etc	6	5000	30 000
Water supply	Pumps and bores per unit	12	8000	96 000
	Holding tanks per unit	5	20 000	100 000
	Water supply pipe work per km	2	5000	10 000
Contaminated land	Survey per event	1	100 000	100 000
	Waste disposal facilities	2	175 000	350 000
	Remediation per event	3	50 000	150 000
Monitoring	Rehabilitation EFA for five years, per visit	5	75 000	375 000
	Surface water and groundwater monitoring per annum	15	80 000	1 200 000
Power station	Powerplant removal (engines)	7	12 500	87 500
Power reticulation	Pole/lines removal per km	20	4000	80 000
Subtotal				10 899 750
Project management	12% of subtotal			13 079
Total estimate				12 207 720

Note: EFA = Ecosystem Function Analysis.

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