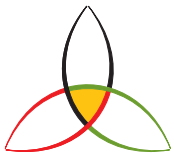




Australian Government  
Department of Resources,  
Energy and Tourism

# EVALUATING PERFORMANCE: MONITORING AND AUDITING

LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY



SOCIAL  
ECONOMIC  
ENVIRONMENTAL

LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY

## EVALUATING PERFORMANCE: MONITORING AND AUDITING



OCTOBER 2009

## **Disclaimer**

Leading Practice Sustainable Development Program for the Mining Industry.

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Cover image: Deleeze Mackey, Environmental Advisor at the Hail Creek Coal Mine, monitoring vegetation at the mine site. Source: Rio Tinto Coal Australia.

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	<p>Ms Tania Laurencont Manager Environment Environmental Services Queensland Department of Environment and Resource Management</p>	<p><a href="http://www.derm.qld.gov.au">www.derm.qld.gov.au</a></p>	
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	Mr David Donato Principal Donato Environmental Services	
	Ms Sophie Pape Senior Environmental Engineer Earth Systems	<a href="http://www.earthsystems.com.au">www.earthsystems.com.au</a>
	Dr Gavin Mudd Department of Civil Engineering Monash University	<a href="http://www.eng.monash.edu.au">www.eng.monash.edu.au</a>
	Professor David Williams Golder Professor of Geomechanics University of Queensland	<a href="http://www.uq.edu.au">www.uq.edu.au</a>
	Dr Catherine Pattenden Centre for Social Responsibility in Mining University of Queensland	<a href="http://www.csr.m.uq.edu.au">www.csr.m.uq.edu.au</a>
	Mr Graham Brown Principal Graham A Brown & Associates	<a href="http://www.grahamabrown.com.au">www.grahamabrown.com.au</a>
	Mr John Bastin Monitoring and Auditing Department of Environment, Water, Heritage and the Arts	<a href="http://www.environment.gov.au">www.environment.gov.au</a>
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## FOREWORD

A strong commitment to leading practice sustainable development is critical for a mining company to first gain and then maintain its 'social licence to operate'.

The handbooks in the Leading Practice Sustainable Development Program for the Mining Industry series integrate environmental, economic and social aspects through all phases of mineral production from exploration to construction, to operation and finally mine site closure. The concept of leading practice is simply the best way of doing things for a given site. Leading practice is as much about approach and attitude as it is about a fixed set of practices or a particular technology.

The International Council on Mining and Metals (ICMM) defines sustainable development as investments that are technically appropriate; environmentally sound; financially profitable; and socially responsible. *Enduring value: the Australian minerals industry framework for sustainable development* provides guidance for operational-level implementation of the ICMM principles and elements by the Australian mining industry.

A wide range of organisations have helped develop this handbook, which will assist all sectors of the mining industry to reduce the impacts of minerals production on the community and the environment by following the principles of leading practice sustainable development.

**The Hon Martin Ferguson AM MP**

Minister for Resources and Energy, Minister for Tourism





# 1.0 INTRODUCTION

## 1.1 Scope and background

This handbook addresses the theme of evaluating performance through monitoring and auditing, which are key elements in the Leading Practice Sustainable Development Program for the Mining Industry. The aims of the program are to identify the key issues affecting sustainable development in the mining industry and provide information and case studies that illustrate how to establish a more sustainable basis for the mining industry.

This handbook addresses the ongoing assessment of impacts at all stages of a resource project, from pre-feasibility through planning, environmental and social impact assessment, development, operation rehabilitation, decommissioning and closure.

Leading practice systems seek to manage financial and sovereign risk by considering and engaging all stakeholders so that outcomes are expressed not just as the financial bottom line but rather as a triple bottom line that includes positive financial, social and environmental outcomes for all stakeholders. While the primary focus of this handbook is on environmental management, there is also an emphasis on the social and economic aspects that are integral components of performance within a sustainable development framework.

Leading practice organisations are now incorporating social considerations into all aspects of their performance evaluation. This takes two forms, both of which are addressed in this handbook: monitoring and reporting local and regional socioeconomic adjustment that may occur as a consequence of mining activity; and engaging the community in environmental monitoring. Leading practice examples of both approaches are inclusive of communities at each stage of the monitoring process from participation in program design through to data collection and reporting.

Mining companies that are recognised for implementing leading practice sustainable development understand that their social licence to operate is largely influenced by their performance in these areas, and they understand the business case for good performance and continuous improvement. They also recognise that assessing and achieving good outcomes is not limited to the immediate and surrounding environment and communities affected by operations, but must cover a larger temporal and spatial scale by taking into account all relevant site, local, regional, national and even international aspects.

The primary audience for this handbook is management at the operational level, the level responsible for implementing leading practice at mining operations and ensuring that monitoring and auditing are conducted to evaluate and improve performance. The handbook is also relevant to people with an interest in performance assessment in the mining industry, including environmental officers; mining consultants; governments and regulators; non-government organisations; neighbouring and mine communities; and students.

While abandoned mines demonstrate the antithesis of leading practice in many ways, it is intended that managers of abandoned mines use the information contained in this and the other program handbooks as one of several resources to plan and implement monitoring and auditing as part of an overall rehabilitation program to transform a site from 'negative legacy' to 'positive inheritance' (Eden Project IUCN/ICMM 2008).

By applying the principles outlined in this and other related handbooks, all users are encouraged to work together in partnership and take up the challenge to continually improve the mining industry's standards of monitoring and auditing, as part of its approach to sustainable development.

## 1.2 Role of monitoring and auditing in leading practice

### **What is 'leading practice'?**

In the context used in this series of handbooks, leading practice is defined as 'the best available current practice promoting sustainable development'. It is important to emphasise that this refers to current practices, that is, accepted approaches or procedures currently being implemented by mining companies. It does not refer to experimental procedures or new processes that appear encouraging at this stage, but may or may not meet their objectives or prove to be cost effective over time.

Leading practice involves stakeholders and is designed to result in good performance outcomes in relation to agreed sustainable development objectives. While recognising that companies must consistently, as a minimum, meet legislative requirements, it also expects them to go beyond the minimum. Leading practice is a changing target—it is adaptive to changing standards and situations that are frequently encountered in major mining operations.

Monitoring and auditing together enable companies and stakeholders to evaluate and improve leading practices.

In the simplest terms, monitoring and auditing are processes designed to help a mining company achieve good sustainable development performance, and verify that this has been done. In broad terms, this can involve tracking progress over time, determining whether agreed objectives or standards have been met, and benchmarking procedures and performance against those of other mining operations.

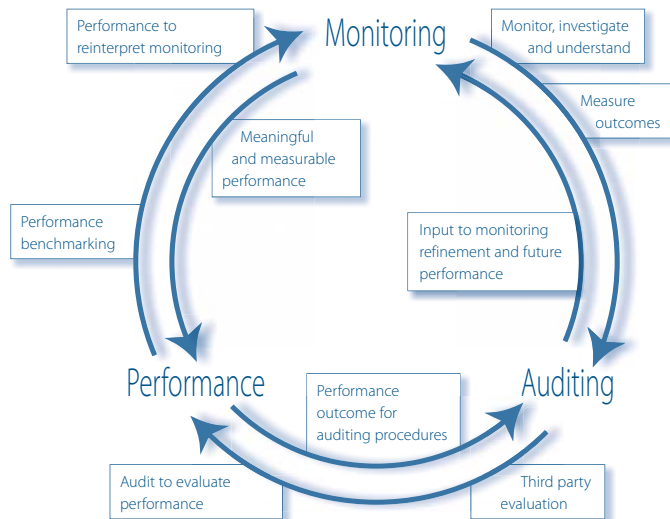
### What is 'monitoring and auditing'?

Monitoring is the gathering, analysis and interpretation of information for the assessment of performance. Examples commonly used in the resources industry include monitoring of water quality, impacts on flora and fauna (as well as recovery following the implementation of control or rehabilitation measures), social aspects and community development, air quality, noise, vibration, greenhouse gas emissions, and the extent to which rehabilitation and final land use objectives are being met.

Auditing is systematically reviewing monitoring procedures and results, and checking that all commitments have been fulfilled or completed by comparing the audit findings against agreed audit criteria. Auditing can be undertaken internally, by experts in specific disciplines who provide a check on methods or success against internal company standards, or externally, by an independent consultant or expert who can demonstrate transparency and add value to the audit process.

In any leading practice environmental management program, the elements of monitoring and auditing for evaluating performance are inextricably linked. This is illustrated below.

### Evaluating performance: monitoring and auditing leading practice schematic



Source: David Donato, Donato Environmental Services.

At the development stage of a greenfield site, procedures are used to identify key components or impacts that need to be monitored and managed at key stages of the mine's life. This is usually done using a risk-based approach which incorporates the following elements.

- Legal requirements are identified, as a minimum standard of achievement for environmental protection and associated monitoring.
- Baseline studies are used to identify environmental, social and economic values and establish monitoring and management programs. This enables companies to commence long-term planning for sustainable development and mine closure before any impacts occur.
- An environmental and social impact assessment is conducted, to enable regulators and other stakeholders to review predicted impacts and mitigation measures. It must be a transparent process based on both good science and extensive consultation, and conducted using an agreed risk management and sustainable development approach.
- Company risk management frameworks are defined to identify potentially 'significant' risks so control measures can be developed and applied, and the success of their implementation can be evaluated.
- Internal company standards and procedures are applied to ensure that the corporate objectives are clear and provide a minimum standard of environmental protection for individual sites to attain.
- Leading practice guidelines from within Australia and overseas (such as the International Council on Mining and Metals principles) provide case studies and frameworks for planning.
- Ongoing monitoring programs are established, to assess real-time and historic performance and, together with research programs, enable continuous improvement by providing information to guide future adjustments to environmental management and monitoring. Rigorous review of the data collected by a monitoring program, conducted at appropriate intervals, is critical to ensure that the monitoring program remains applicable and enables impacts to be measured.
- Recognising that every mining project and community is different, research is conducted to address gaps in knowledge and develop innovative solutions to problems. Together with the feedback from monitoring, the information gathered through research linked to leading practice monitoring principles is a key element of the continuous improvement loop.
- Audits are used to evaluate compliance with regulatory requirements, company standards and/or other adopted systems and procedures. This helps industry to demonstrate its performance to stakeholders and encourages continuous improvement. When audits of monitoring programs identify gaps in knowledge or inadequacies in control measures, they enable monitoring programs to be improved.

Often, these elements are part of an environmental management system in compliance with AS/NZS ISO 14001:2004 *Environmental management systems—requirements with guidance for use*. An environmental management system helps the company to achieve leading practice by providing a framework for the development and regular review of procedures used to assess, mitigate and manage environmental impacts.

These elements are adapted to monitor and audit the performance of brownfield sites, depending on the site and its context, including the physical and social aspects, the age of the mine, key risks/issues and the historical evolution of the site and its ownership.

This handbook describes how mining companies integrate all of these elements over the life of the mining operation, to achieve leading practice sustainable development. The handbook outlines the key principles and procedures now recognised as leading practice for monitoring and auditing to evaluate performance, namely: assessing and managing environmental, social or economic values, and identifying, minimising and managing any primary, secondary or cumulative impacts on those values. Leading practice requires the principles to be addressed over the whole potential project sphere of influence, always in consultation with government and other key stakeholders, and often in partnership with non-government organisations.

A number of case studies are used to illustrate and reinforce the approaches outlined in the handbook.

Most of the environmental, economic and social aspects discussed in the handbook are relevant to both open-cut and underground mines. However, it should be noted that some issues specific to underground mines, such as subsidence, underground coal gasification and geothermal aspects, are beyond the scope of the handbook. For sites where there may be risks associated with such issues, readers are urged to consult other relevant publications and information sources. Occupational health and safety matters are also not covered except where they are directly relevant to the monitoring and auditing issues discussed.

### **1.3 Deficiencies in current monitoring and auditing practices**

While focusing on leading practice, it is useful to understand the key deficiencies of past monitoring and auditing practices, in order to avoid repeating them. Commonly encountered deficiencies include:

- lack of a clearly defined purpose for the monitoring program and/or audit process, leading to unsatisfactory outcomes, wasted resources and potential conflict with stakeholders because expectations are not met
- dysfunctional feedback loops, meaning that data are not analysed or the analyses are not used to enable continuous improvement
- performance measures that are too narrow and fail to include adequate socioeconomic and environmental perspectives
- an inappropriate level of public reporting, meaning that the purpose and context of monitoring and auditing are not clearly understood



- monitoring plans that are not able to proactively respond to long-term life cycle issues because key elements are largely focused on start-up issues, and adequate baseline data for managing long-term issues have not been obtained
- timeframes for review that reflect regulatory requirements but are not necessarily structured to address problems
- annual monitoring reports that are treated as a regulatory compliance requirement only, and not integrated with a focus on performance and high-level review using appropriate skills
- inappropriate or inadequate use of risk assessment methods to provide additional checks on monitoring needs.

## 1.4 Links to the impact assessment process

Environmental impact assessment (EIA) has been required by state and Commonwealth governments in Australia for more than three decades. The scope and statutory basis for EIA is always changing, as community knowledge and expectations mature, technology improves, projects become larger in scale and/or the status of regions changes. EIA has evolved over the past decade from being largely focused on environmental issues to more explicitly accounting for social or economic impact assessment and planning, with increasing emphasis on combined environmental and social impact assessments. Changes in EIA are expected to continue, and the emphasis on sustainability is likely to become more important for future mining projects.

The primary basis for impact assessment is to examine the potential impacts of any project before it proceeds, so that a fair and balanced decision can be arrived at as transparently as possible. Impact assessment can also be required prior to a significant expansion or change in project scope, such as going underground after being open cut.

Impact assessment is a fundamental procedure that links closely to both monitoring and auditing. For example, monitoring systems play a key role in the initial assessment of values and likely impacts, while the establishment of environmental management programs to minimise ongoing impacts and facilitate recovery or rehabilitation requires monitoring, research, auditing and overall performance evaluation.

Leading practice sustainable development increasingly requires the use of impact assessment tools in a multidisciplinary manner which goes above and beyond the requirements of legislation alone.

### **What are the different types of impact assessments?**

Environmental impact assessment (EIA) is an assessment of the possible impacts—positive or negative—that a proposed project may have on the environment and the affected community, including impacts on heritage values and economic impacts. At the federal level, EIA provisions are contained within the *Environment Protection and Biodiversity Conservation Act 1999*. At the state level, EIA provisions are typically contained in land use planning law. The three types of environmental impact assessment, in order of depth and thoroughness, are: a public environment report, an environmental impact statement or a full public inquiry.

Environmental and social impact assessment is an assessment which incorporates both a social impact assessment and an EIA, which may have been undertaken separately in the past, and explicitly accounts for social or economic impact assessment and planning.

Socioeconomic impact assessment (SEIA) is an analysis of the economic impacts of a proposed project on communities, as required by leading practice in both life-of-mine-planning and impact assessment. The Sustainable Minerals Institute at the University of Queensland and the Minerals Council of Australia have methods for conducting SEIAs.

Guidelines for EIA in Queensland and some other states now specifically require social and heritage values to be included.





## 2.0 SUSTAINABLE DEVELOPMENT

### 2.1 Guiding principles

The application of sustainable development principles to mining has undergone rapid evolution in the past decade, in concert with the global trend in commitment to sustainable development generally. The Minerals Council of Australia (MCA) has developed *Enduring value: the Australian minerals industry framework for sustainable development* to articulate and implement sustainable development within the Australian mining industry (MCA 2004). The International Council on Mining and Metals (ICMM) has also developed a sustainable development framework, covering principles, public reporting and independent assurance. The principles directly relevant to this handbook are 4, 5, 6, 7, 9 and 10 (ICMM 2006).

A core principle in sustainable development is the 'precautionary principle', which is simply stated in the 1992 *Intergovernmental agreement on the environment* as:

where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. (DEWHA 1992)

Monitoring and auditing are critical for underpinning sustainable development and applying the precautionary principle, since the information they provide is crucial in assessing and managing the extent of impacts. This chapter describes the main methods and standards for adopting leading practice by incorporating sustainable development principles into performance evaluation programs.

#### 2.1.1 National and international standards

Government policy and corporate policy are becoming increasingly committed to sustainable development. In general, both sectors might commit to high standards and use of available international protocols, but often leave implementation to individual companies. For example, ICMM members are committed to responsible mining practices (as described in the ICMM 'Good Practice Mining' resources available through [www.icmm.com](http://www.icmm.com)), but ICMM does not provide detailed, prescriptive guidance; rather, it recommends an approach which is flexible and able to be tailored to specific companies or mining projects.

There are many standards or protocols which seek to facilitate the operational implementation of sustainable development principles. They include voluntary industry protocols such as the ICMM principles or MCA's *Enduring value*, as well as numerous relevant standards from the International Organization for Standardization (ISO) and Australian/New Zealand Standards (AS/NZS) for various aspects of monitoring.

The World Bank International Finance Corporation has developed a series of *Performance standards on social and environmental sustainability*, as well as *Environmental, health and safety guidelines for mining and Environmental, health, and safety general guidelines (General EHS guidelines)*, which are relevant to

environmental and social monitoring and auditing (IFC 2006, 2007a, 2007b). In addition, an increasingly popular protocol is the Global Reporting Initiative (GRI), which was established by the United Nations in conjunction with governments and civic and industry groups specifically to facilitate consistency and transparency for sustainability reporting (GRI 2006). Although these protocols are essentially voluntary in nature, compliance is increasingly being expected as evidence of good corporate governance.

The GRI provides a framework for annual reporting of a wide range of information and data, with a view to demonstrating progress against sustainable development objectives. It includes qualitative or quantitative indicators covering human rights and economic, social, environmental and labour practices. The GRI has been widely adopted by most major mining companies. Although it could be perceived as standard practice for larger companies, it provides the opportunity to demonstrate a company's commitment to positive outcomes in various sustainability areas, such as water resource protection, biodiversity conservation, education and social investment. On the other hand, it allows a company to acknowledge problems and outline planned responses to resolve them.

Sustainability reporting, based on the GRI, allows a company to publish its ongoing information, which could include monitoring data, safety performance measures or independent audits, thereby demonstrating transparency and accountability. The GRI also addresses social aspects, and includes a range of social indicators to be monitored and reported against. For example, many mining companies operating in South Africa need to monitor issues such as HIV/AIDS and economic empowerment. In developing countries or regions, the United Nations Millennium Development Goals (published at [www.unmillenniumproject.org](http://www.unmillenniumproject.org)) are also critical with respect to monitoring and auditing industry performance, and are almost certain to grow in importance across the global mining industry.

## 2.1.2 Legislation and regulation

### Australia

There is a range of state and Commonwealth legislative requirements relevant to monitoring, auditing and performance for mining—such as the requirements for environmental impact assessment, surveying and monitoring of species or ecosystems listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and regulations for monitoring air or water quality, pollutant discharges and so on. Many of these requirements are commonly included in mining leases and other statutory licences and conditions.

State governments have the primary constitutional power to manage the environment, and to issue mining titles and environmental or pollution control licenses. Different states have different requirements and expectations for monitoring, auditing and performance. However, leading practice helps to ensure consistency across all jurisdictions by identifying regulatory requirements and aiming for performance outcomes which are clearly in excess of these. In relation to the EPBC Act, consistency between state and Commonwealth government requirements is also increased by the fact that the process can be delegated so that only one set of environmental and social impact assessment requirements has to be met to

comply with all Commonwealth, state or territory legislation or local government requirements.

Commonwealth legislation encourages companies to undertake research by enabling them to take advantage of tax incentives for the implementation of innovative and systematically planned studies. Sustainability research is often integrated with monitoring, particularly in areas where new solutions to site-specific problems are needed. Under the Australian Government's National Pollutant Inventory, specific pollutants emitted above minimum thresholds are required to be monitored (or estimated) and publicly reported.

Although compliance with the legally required measures alone cannot be considered leading practice, it is important to note that companies recognised for leading practice consistently meet regulatory requirements, including for monitoring and auditing, and report both as required and on time. Also, in some instances, companies demonstrate leading practice by undertaking these activities in a way which far exceeds normal statutory requirements.

### **International**

In the international sphere, monitoring will become increasingly important for either environmental management and/or business case purposes.

A major growth area for monitoring and performance is greenhouse gas emissions. The legislative and international basis for emissions accounting and reporting is undergoing rapid evolution. Many governments around the world are pursuing progressive action, recognising that the Kyoto Protocol agreement period expires in 2012.

Trade restriction is another critical area. The European Commission's 2006 Regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) aims to provide for detailed assessment of the potential impacts of pollutants of products balanced against the desire for protecting human health, the environment and industry competitiveness. For example, excessive arsenic levels in metal concentrate or technologically enhanced naturally occurring radioactive materials may preclude export to Europe under the REACH regulations. Therefore, a company exporting products to Europe must ensure that it monitors product quality and associated aspects to ensure they comply with the regulations, or risk being excluded from a key economic market. For more information, see the leading practice handbooks *Risk assessment and management* and *Stewardship* (DRET 2008; DITR 2006b).

### **2.1.3 Community expectations**

It is normal for local communities in the vicinity of mining or mineral processing projects to want to stay informed about environmental aspects, social investment, economic contributions, statutory obligations and the like.

Historically, the mining industry has at times failed in its ability to provide timely information to stakeholders and the broader community about all aspects of particular mining operations. In terms of achieving leading practice in this area, companies are becoming aware of what the community expects to know about mining operations and are setting up frameworks to identify stakeholders and their

expectations, collect monitoring and auditing data over the life of a project, and report to the community. This is part of a company's 'social licence to operate', as noted in *Enduring value*.

The combination of sustainability reporting guidelines (see Section 4.13) and the ease of publishing through the internet is facilitating a revolution in the ability of mining companies to demonstrate their successes and challenges and meet community expectations for performance evaluation. For many community members, leading practice requires a detailed, up-to-date and transparent website with live, online monitoring data. For specific projects it is important to develop appropriate communication strategies which are relevant to local community needs and expectations as well as cultural practices, especially in impoverished or Indigenous communities, as described in the leading practice *Community engagement and development* handbook (DITR 2006a).

## **CASE STUDY: Life-of-mine biodiversity monitoring**

As part of its biodiversity monitoring program, Rio Tinto Iron Ore (RTIO) conducts baseline biological surveys well ahead of its mining operations in the Pilbara region of Western Australia. Surveys include flora, vegetation, terrestrial and subterranean fauna, and targeted short-range endemic searches. In an environment that is remote and not well studied, encountering new or poorly known taxa has become a regular occurrence, and the time it takes to resolve issues such as positive identification, conservation status and habitat requirements can be lengthy.

Where there is deemed to be some risk of direct impacts from mining operations, flora, fauna and vegetation communities may be monitored for the life of the mine. It may also be necessary to monitor biodiversity some distance from the mine, at sites where secondary impacts associated with infrastructure (for example, altered hydrology, weeds and creek discharge) may occur.

Significant habitats, such as riparian and subterranean ecosystems, that may be impacted by mine dewatering activities are being monitored for many years before mining commences, using a variety of techniques such as remote sensing, vegetation transects, fish and macroinvertebrate (including stygofauna) sampling, and canopy photography. Gathering many years of baseline data reveals the degree of natural variability in a highly dynamic environment such as the Pilbara, and can be used to help determine whether mine-related impacts have occurred.

Biodiversity monitoring continues through the operational phase and enables RTIO to assess and improve its rehabilitation performance by developing a better understanding of key procedures such as erosion control, topsoil handling and seeding. The company's operations in the Pilbara are conducted in semi-arid areas where rainfall is low and unpredictable, and recurrent fires occur. Because

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of this, successional development may not follow expected trends, and therefore needs to be monitored so that it can be understood, enabling continuous improvement of rehabilitation operations and management. Data obtained from monitoring key vegetation parameters such as plant cover, density, richness and diversity will also assist in the development of completion criteria.

In addition, RTIO is the lessee of six pastoral leases in the Pilbara region, which adjoin mining areas and cover a combined area of over 1,500,000 hectares. While the company operates these as pastoral enterprises, it is also committed to managing to conserve and enhance biodiversity values within each of the pastoral stations, to comply with RTIO environmental standards and relevant government requirements. Best standard sustainable land use objectives are defined, incorporated into environmental management plans, and met where possible. The aim is to establish ecologically sustainable rangelands that can be transferred to the Western Australian Department of Environment and Conservation in the future.

## 2.2 Risk planning and management

Risk planning and management is an integral component of sustainable development. Potential risks need to be identified and evaluated against relevant criteria, and potential control measures need to be designed and implemented, based on standards such as AS/NZS 4360:2004 *Risk management*.

Given the wide variety of risks that a mining project faces, including economic, environmental, social, reputational and even political risks, it is vital that there is clear alignment between monitoring and auditing and risk management. If a specific risk is identified (for example, a potential tailings dam failure), monitoring must incorporate aspects which allow this risk to be appropriately managed (for example, monitoring of groundwater pressures, underdrainage and so on), and auditing must ensure that the required monitoring is carried out and performance evaluation addresses the level of success achieved in managing the risks. The incorporation of risk assessment and management procedures into monitoring design is discussed in more detail in Section 3.1.

## 2.3 Environmental and social impact assessment

As the focus of stakeholders and regulators moves increasingly towards sustainable development, this is being reflected in government policies and legislation relating to impact assessment. For example, the EPBC Act specifies seven areas for Commonwealth involvement in environmental impact assessment, namely: world heritage properties, national heritage, wetlands of international importance, listed threatened species and ecological communities, migratory species protected under international agreements, Commonwealth marine areas, and nuclear actions (including uranium mines). Relevant state and territory policies and legislation are listed in the 'Further reading' section at the end of this handbook.

Although the details vary between jurisdictions, there are normally three levels of increasing impact assessment: a public environment report, an environmental impact



statement or a full public inquiry. The level of assessment required is commonly determined through a referrals process to the relevant agency or the relevant Minister. In general, the larger or more controversial a project is, the higher the level of impact assessment required.

A major point of standard practice is to incorporate the environmental management system into the impact assessment process, and link baseline studies to monitoring requirements and performance criteria. Leading practice involves going beyond simple legal compliance to incorporate new areas (such as social aspects or climate change criteria) or a broader range of project options, to better manage risks (see Section 3.1).

In the future, as sustainability continues to drive evolution in the area of impact assessment, presenting a broad approach will require project proponents to link the technical, social, financial, environmental and regulatory spheres to ensure the best sustainable outcomes for the environment and all stakeholders.



## 3.0 MONITORING: DESIGN

### Key messages

- Planning for monitoring over the life of the mine is most cost-effectively based on assessment of the key environmental and stakeholder risks, and changes to the community asset base, for each phase of operations.
- Regular review of the risks and associated monitoring is needed to ensure objectives are met and findings are used to inform improved management decisions and practices.
- Monitoring is the means by which mining companies and stakeholders can assess the effectiveness of management measures, verify or adjust predictions made early in the project, and develop improved management practices.
- Leading practice mining project monitoring programs comprise environmental, social, cultural and socioeconomic aspects, in addition to routine operational monitoring requirements.

### 3.1 Planning to manage risk

Leading practice monitoring extends beyond the minimal monitoring that may be required for assessing compliance with licence or operating conditions. Leading practice monitoring is designed to be sensitive enough to detect trends in key parameters well before they go out of compliance, and to enable prompt response to concerns or allegations of impact from third parties. In other words, leading practice monitoring is risk based and proactive. It needs to be focused on the key environmental risks for the site, which will include compliance risks as well as other potential stakeholder concerns, and to be cognisant of those risks at each stage over the life of the mine from exploration to closure (and beyond, for some aspects). It can serve as a valuable planning tool, helping to define the skill sets required to achieve leading practice, and assisting in the process of adjusting to change during the life of the mine.

Monitoring that is only able to detect changes after an impact has occurred cannot be used to manage systems to prevent impact and minimise liabilities. A common misconception is that monitoring for compliance is sufficient to manage impacts. If the first measurement of change is one that fails compliance, it is too late to prevent the unwanted impact, as most compliance standards are set at the point where, if compliance is not maintained, impact will occur—see, for example, the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000).

Risk planning for monitoring involves understanding the nature and relevant sensitivities of the project, including environmental, political, socioeconomic and cultural contexts, and the processes by which mine operations could affect them. This enables appropriate, sensitive parameters and endpoints to be selected and used to detect underlying trends before detrimental impacts occur. The leading practice handbook *Risk assessment and management* (DRET 2008) includes

examples of risk assessment that are applicable to risk planning for monitoring. Tables 3, 4 and 5 in that handbook provide useful examples which can be adapted to suit a specific operation and context. It will be necessary to insert additional specific descriptors into a consequence table (such as Table 5) to ensure monitoring, auditing and performance are addressed adequately for an operation.

One method of incorporating risk planning into the monitoring program is to develop a risk register which incorporates life-of-mine risks and monitoring with the completion criteria relevant to each. Separate risk registers can be developed for each phase of operations from exploration to closure, and updated as the operation progresses. A risk register can provide both a framework to identify significant risks and the control measures to mitigate those risks (which is recommended as part of an environmental management system under ISO 14001:2004, or any other mechanism for managing impacts).

An environmental and social impact assessment (ESIA) will need to include a risk register with likelihood and consequence assessments and, ideally, a designed monitoring system to quantify potential impacts. Some research may need to be carried out, either as a desktop study or hands on, if there is insufficient information to define or quantify potential impacts. The monitoring commitments made during the ESIA process need to be adhered to and revisited periodically in case changes are required (see Section 3.3).

The risk register can be developed through a number of mechanisms—for example, assessments by panels of experts with diverse skills, stakeholder consultation, or quantitative and semi-quantitative risk assessments. An effective risk assessment process must have the appropriate skills-knowledge mix in the team developing it, with high-level commitment to implementing the control measures once identified, supported by the budget and resources to undertake necessary actions.

The *Risk assessment and management* handbook provides examples of each type of risk assessment. Further guidance is provided in the Australian and New Zealand Standard AS/NZS 4360:2004 *Risk management* and Standards Australia handbook HB 203:2006 *Environmental risk management—principles and process*. Standards Australia also provides guidance on managing specific risks in handbooks such as:

- HB 205-2004 *OHS risk management handbook*
- HB 231:2004 *Information security risk management guidelines*
- HB 294:2006 *National post-border weed risk management protocol*.

While the Australian and New Zealand Standard is based largely on qualitative risk assessments, it is compatible with quantitative risk assessments. Good examples of quantitative risk assessment occur for occupational health and safety purposes (see HB 205-2004), but they are less commonly conducted for environmental risk assessment. Further guidance on quantitative environmental risk assessment can be obtained from the United States Environmental Protection Agency (through the website at [www.epa.gov/risk/ecological-risk.htm](http://www.epa.gov/risk/ecological-risk.htm)), which describes an approach that has been widely used for mining projects in the United States and Papua New Guinea. Quantitative risk assessment provides for more precise assessment and ranking of risks for each phase of operations, but any formal process of risk assessment and risk register development will provide a justified list of key risks.

Knowledge of the key risks, the ways they are likely to vary over the life of the project and the potential environmental responses to them will facilitate the development of a monitoring program that:

- includes parameters relevant to the key risks over the life of the mine, not just the parameters likely to appear on an environmental permit
- adapts to and pre-empts changes in the key risks over the life of the mine, rather than being based on a 'one size fits all' or reactive approach which cannot adequately manage liability
- goes beyond compliance monitoring to focus on trends in the key parameters, with sufficient sensitivity to provide early detection of trends at the appropriate times
- is based on sound, substantiated knowledge of the likely sensitivities and responses of the receiving environment and stakeholders.

The risk planning approach minimises the potential liabilities of the operation in each stage, by providing adequate warning of potentially detrimental trends, ensuring appropriate datasets are available when issues arise, and minimising the chance of being unable to defend unanticipated claims. The key is to manage risk for all stages of the operation, and to ensure that the baseline and reference datasets have sufficient accuracy and precision to enable adequate assessment of risk for each key parameter in each stage of the operation.

There are risks associated with the gathering of appropriate information to solve problems and answer key questions. Additionally, there are more fundamental risks associated with data collection and management to ensuring the continuity and accessibility of data. Both aspects must be addressed during the risk assessment. During auditing, there is a risk of 'lack of rigour'—that is, that the auditing team may lack the appropriate skills to understand the requirements of a robust monitoring program or the specific impacts of concern at a site, and fail to pick up on any inadequacies.

Leading practice monitoring requires the risk assessment process to recognise and address risks associated with monitoring, such as the possibility that:

- baseline monitoring is not carried out over a sufficiently representative time period or location to provide good quality data upon which to base a mine site water balance
- monitoring installations are destroyed by vandalism, fire, flood or feral animals, causing loss of data at critical times
- databases used to manage and interpret data change over time and old data becomes irretrievable
- personnel who understand the critical elements of a monitoring program do not document procedures and, when they leave the company, new personnel are unable to manage the monitoring system to the standard required
- monitoring data are reviewed annually but not over the life of a project, so cumulative impacts go undetected
- monitoring focuses on indirect measures of impact and therefore fails to detect the impacts which need to be measured.

## 3.2 Life-of-mine planning and management

Life-of-mine planning for monitoring requires a predevelopment impact register to be formulated and risk assessment procedures to be carried out, as described in Section 3.1. Once all potential future impacts have been identified, monitoring systems can be designed and put in place to take account of them.

### 3.2.1 Baseline monitoring

Where it is possible to incorporate baseline monitoring (for example, with greenfield projects and expansions to mines), such monitoring is a critical component of leading practice monitoring programs. Baseline monitoring should commence at the pre-feasibility stage and include all relevant environmental, economic, and social issues identified in risk planning. Typical elements of monitoring programs are listed in Appendix 2.

In most cases, the baseline monitoring system will need to be permanent so that repeat assessments can be made. This will provide essential data on several aspects not necessarily related to impacts of the mining project, such as natural variability over time and place, and pre-existing impacts due to previous mining projects, other current mining projects or other causes. These data are essential for correctly interpreting the results of monitoring programs that have been designed to assess the extent of mining project-related impacts and recovery following control of the impact or rehabilitation.

### 3.2.2 Design principles for monitoring

A common approach for assessing impacts and recovery is the use of the 'before-after-control-impact' (BACI) monitoring design (Quinn & Keough 2006). The 'before-after' component refers to time prior to and subsequent to any project-related impact. 'Control-impact' refers to areas assumed to be unaffected ('control') or potentially affected ('impact') by the project. In this context, it is important to note that impacts can include direct impacts, secondary impacts, and cumulative impacts.

The principle of the BACI design is that the mining operation's effect on the environment is assessed by determining the interaction between measurements taken before and after the impact at sites at risk and comparable sites not at risk. However, the time and duration of impact, or even whether an impact has occurred, may not be clear. Therefore monitoring must take place before there is the possibility of any impact, and over the time when potential impacts could occur.

Other aspects to note include:

- While the 'control' and 'impact' sites should be similar, it is not necessary and not always possible for them to be identical. However, the differences between the sites must be measurable both before and after the possible impact.
- If the project has had an impact, the differences between the 'control' sites and the 'impact' sites may have changed. It is this difference that can be measured and used to statistically determine whether an impact has occurred.

## CASE STUDY: Incorporating baseline studies into ongoing monitoring programs

Hail Creek Mine is a large open-cut coking coal mining operation located in central Queensland and operated by Rio Tinto Coal Australia (RTCA). Construction of the mine commenced in December 2001 following extensive environmental baseline studies.



Hail Creek Mine site. Source: Rio Tinto Coal Australia.

The original open woodland had previously been extensively thinned to improve grazing; therefore, the immediate mining lease area is generally degraded. To the north and east of the mining lease, there are areas with higher conservation values, including Homevale National Park and non-grazing land to the north of the mine. The primary catchment in which Hail Creek Mine lies flows through the Dipperu National Park approximately 54 kilometres downstream; therefore, the protection of water resources for aquatic ecosystems is important.

Since the commencement of mining operations in 2003, monitoring and research programs have been implemented to validate the environmental controls and ensure the environmental values of the surrounding area are preserved and enhanced. Development of the mine required the diversion of Brumby Creek, with potential impacts on the *Eucalyptus raveretiana* (Black Ironbox), which is listed as vulnerable under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). A number of management commitments were made, including the development of an annual monitoring program to assess and manage potential impacts on this species resulting from the creek diversion.

A biodiversity values assessment of all land managed by the mine was undertaken in order to identify areas of high biodiversity values and develop corresponding management initiatives. Annual surveys of the lease are undertaken for the two threatened fauna species identified during the baseline

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survey works, the Ornamental Snake and Little Pied Bat, both of which are listed under the Nature Conservation (Wildlife) Regulation 2006 and EPBC Act.

The baseline surface and groundwater quality monitoring program developed prior to the commencement of mining operations allows RTCA to detect potential changes due to impacts from mining, based on results from routine water sampling programs, with additional monitoring completed during rainfall and authorised discharge events. The baseline ecological stream health assessment for areas both upstream and downstream of the mining operations area also assists with the assessment of any impacts identified.



**Hail Creek. Source: Rio Tinto Coal Australia.**

Annual surveys, based on those completed prior to mining, continue to assess overburden and rejects for acid and metalliferous drainage potential. The assessment is further supported by sampling conducted during exploration drilling adjacent to the current mining activities.

A research project designed to improve the success of rehabilitation has commenced. This will build on baseline soil assessment work to determine germination success on different soil types, and help determine rehabilitation success criteria.

Prior to the commencement of operations at Hail Creek a program of community consultation was completed. This provided the basis for understanding the expectations of the local community and assisted in creating robust community relations strategies, developing relationships and mitigating potential community impacts. Hail Creek Mine now assesses any changes in ongoing views and concerns through regular communication with the local landholders, community and government.

A socioeconomic baseline study for all RTCA operations in the Bowen Basin has recently been completed. This will further assist in understanding potential impacts on the community and how these impacts can be mitigated, as well as identifying opportunities for future community programs.

In practice, the BACI monitoring design can sometimes be more complex than this, and may require a modified BACI design, although the principles will remain the same. Further details for BACI are given in Quinn & Keogh (2006) and Underwood (1991), while modified BACI is described in Humphrey et al. (1995), Humphrey & Pidgeon (2001) and Faith et al. (1995).

Other impacts not necessarily related to mining operations may need to be taken into account in monitoring design. These can include slash and burn agriculture and artisanal alluvial mining (both of which may increase sediment load upstream of the mine); dust storms, bushfires or forest fires affecting air quality; or previous logging, hunting or clearing activities affecting biodiversity.

Regardless of whether or not the BACI approach is used, monitoring programs should be designed to be cost effective, and according to sound statistical principles or social science research principles. The key to good monitoring design is to fit the design to statistical principles, rather than try to fit statistics to the design. This will help avoid bias in sampling, and enable sample sizes and sampling frequencies to be calculated. Leading practice monitoring programs commonly take statistical power into account, thereby ensuring that, if an effect occurs, there is a high probability that it will be detected.

While parametric statistical analysis using normally distributed data is preferable when determining whether impacts have occurred, in practice high variability or low sample sizes may prevent its use. In this case, the monitoring program may be designed according to non-parametric analysis procedures, making use of modern robust, generalised or Bayesian statistical procedures that are more able to reliably analyse limited datasets and datasets that otherwise do not comply with the underlying assumptions of standard classical procedures. In some cases it may be possible to do little more than observe trends graphically; however, this can prove very useful in understanding what is happening, and communicating the results of monitoring.

Whatever the case, it is essential to include consideration of what analyses will be carried out when designing the monitoring program. Green (1979) provides a list of ten principles that should be taken into account (see Appendix 1), and notes that 'if you have delayed seeking expert advice until you can only ask "what can I do with my data", you richly deserve, at that point, any answer you get!' In other words, consideration of data analysis requirements at the design stage can result in much more cost-effective monitoring programs by providing guidance on sampling locations, intensity, frequency, duration and other key aspects.

Mine planners must be consulted when designing monitoring programs, and in some instances they should actually design the monitoring—for example, acid and metalliferous damage operational sampling for delineation of materials for separation, isolation and/or encapsulation. The monitoring program and the resulting output data should be linked to the mine's spatial or geographic information system (GIS) and should be accessible and highly visible on the system. In this way, when mine plans change (as they often do), those responsible for the monitoring system have early notice and can take action to ensure that impacts due to changes in mining operations are monitored. A particularly important example of this is where monitoring or reference sites are damaged or destroyed, and continuity of the data



record is lost. A good GIS can not only store locations of monitoring sites, but also include monitoring data.

At some sites, companies will decide (or be required) to develop or modify a monitoring program without the benefit of baseline monitoring and a pre-development risk register. This can happen when companies acquire an existing operation, when mining operations recommence in the vicinity of old abandoned mines, or when a decision is made to significantly modify or upgrade the existing monitoring program in line with current regulatory and community expectations. In these instances, careful thought will need to be given to the design of the monitoring program, using the principles described above where possible. Approaches such as monitoring nearby reference sites, monitoring upstream versus downstream, and determining whether previous owners or regulators have conducted monitoring can help in designing an appropriate monitoring program. In situations where a number of mining operations are present, including closed or abandoned mines where no company has ongoing management responsibility, monitoring in conjunction with regulators may be required.

The monitoring program should carry on through the entire life of the mining project, including rehabilitation and closure. Post-closure monitoring will also be required where impacts have the potential to be high risk and/or of long-term duration, for example, where drainage from the mine may be acidic or contaminated. The design and duration of post-closure monitoring and responsibility for conducting it should be determined by agreement with relevant regulators. Once the mining company has demonstrated that the rehabilitation has been completed satisfactorily and is performing as required, post-closure monitoring may be carried out by regulators rather than by the mine or consultants, provided an agreed source of funding is available.

Overall, it is essential that monitoring programs be designed according to the defined risk and potential impact, including positive impacts. They must have clear objectives and, where possible, should be quantitative or incorporate qualitative data that complies with leading practice social science research and is in a form that may be replicated longitudinally. Subjective measures should be used with caution. For example, assessment of erosion using visual inspection is influenced by individual variability and opinion. Measures such as number of erosion gullies per unit length across a slope, or the length, width and depth of erosion gullies, provide a more objective and repeatable means of quantifying the extent of impact and change over time. The same applies to social, socioeconomic and cultural measures—these too need to be designed according to likely risks and potential impacts, in consultation with stakeholders, and to be objective where possible (see examples in sections 3.4 and 4.5 and Appendix 2).

For social performance monitoring, objectively measurable datasets, such as local employment statistics, changes in regional health profiles or surveys of household income and expenditure, may be complemented by well-designed, qualitatively focused monitoring. An example of qualitative monitoring may include tracking of career progression for Indigenous employees and the factors that influence employment outcomes, the essence of which cannot be captured in quantitative or statistical data alone.

## CASE STUDY: Enhanced transparency in water quality assessment

The Northern Territory Government's Department of Regional Development, Primary Industry, Fisheries and Resources undertakes an environmental water quality check monitoring program to track and regulate the environmental performance of selected mine sites identified as carrying high environmental risk in relation to water management. This is especially important given the intensity of the wet-dry monsoonal climate in the Top End, and the relative isolation of operations in Central Australia.

The check monitoring program includes the collection of ground and surface water and, in some instances, sediment and biological samples (macroinvertebrates and fish), and the installation of automatic loggers. In addition, selected programs are designed to provide a broader assessment of potential impacts on larger catchments from multiple mining operation point sources. The program serves as a comparative tool to independently evaluate monitoring data provided by the operators and assess how they are tracking in relation to their commitments under the Northern Territory *Mining Management Act 2001*.

High-risk sites are identified through a risk assessment process repeated annually (or at a greater frequency if required). Some key components of the risk assessment comprise:

- existing ground and surface water impacts and their potential for change, exogenous influences, acid/neutral mine drainage, or the quantity and quality of historical performance and baseline data
- assessment of the operator's resources, environmental management systems, diligence with respect to data submission and quality, breadth and adequacy of existing monitoring programs and operational status.

Once a high-risk site has been identified the operator is required to submit:

- water quality and other identified monitoring data on a quarterly basis or at agreed intervals
- a detailed water management plan, which must be submitted three months prior to the submission of the mining management plan, required under the Act, approval of which represents the site's authorisation to operate.

In parallel, the department also:

- reviews existing monitoring data, to develop new or modify existing departmental check monitoring programs and provide recommendations regarding the operator's programs

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- undertakes a field sampling program with water samples collected and analysed
- uploads data into the department's environmental spatial database, and reviews and interprets results with reference to relevant standards and guidelines or agreed site-specific trigger values
- prepares mine water quality status reports on the overall performance of the mine site relating to ground and surface water management
- reviews the operator's water management plan, which outlines the operation's water management performance—once the document is considered to have demonstrated sufficient technical rigour, it is recommended for approval under the Act
- audits the operation for compliance with commitments under the Act.

To ensure high-quality sampling, the Northern Territory Government has invested in a custom-built 4WD mounted module locally known as the 'Lab Truck', the functions of which provide considerable advantage over monitoring conducted in open air. The module provides a controlled environment that significantly reduces contamination of water samples with airborne matter and prevents oxidation of the sample by preventing exposure to air. This is particularly important in measuring operations where contamination limits may be close to background levels, for example, within Kakadu National Park.



'The Lab Truck'—a purpose-built 4WD mounted environmental water quality sampling unit. Source: Northern Territory Government.

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This joint evaluation of mine environmental performance relating to water management is important for the regulation of operating and non-operating mine sites under the Act, and supports the government's commitment to regulate uranium mining under Northern Territory and Commonwealth agreements. The meeting of these commitments by operators also establishes their commitment to operating in a sustainable and responsible manner.

In a situation where early reporting and joint performance tracking is not successful, as a remaining option, the program also provides legally defensible data for the prosecution of environmental incidents and accidents.

The department has found that regular interaction with mine operators is beneficial in ensuring that environmental monitoring is effectively linked to management strategies within the operator's environmental management system. Additionally, this cooperative and iterative approach provides assurance to the community that environmental concerns are being adequately and independently managed.

### 3.3 Adjustments for changes in the mine plan

Monitoring programs need to be planned and documented in such a way that when changes occur to an operation and new or altered impacts are possible, it is a straightforward matter to adjust the monitoring program.

Ideally, individual monitoring tasks are defined within both a medium-term timeframe (such as one year or five years) and a life-of-mine plan for a particular project. The medium-term plan documents all phases of monitoring and indicates lead times required, particularly when a 'scope-of-works' statement needs to be defined for a monitoring project, and subcontractors/consultants are required to develop proposals prior to commencement.

At the commencement of planning a mining project, or at a key change in an operation's production plan (for example, a delayed start date, expansion or reduction in production, or suspension of operations), the following planning phases should be addressed.

- A risk assessment which identifies monitoring needs and clarifies the purpose of each task for each phase of the operation informs the planning.
- A monitoring plan is prepared for the year ahead on the basis that the risk assessment will focus on the needs/risks that require attention over the coming year and will list all tasks and show interrelationships. Medium-term and life-of-mine monitoring plans are also revisited and updated annually; the level of detail is not as great as for the annual plan, but indicative costs and critical commencement dates are included to support budget submission when needed.

- For individual tasks within the annual plan:
  - objectives are defined and documented in a scope-of-works statement with supporting information
  - if external expertise is required, the scope-of-works is used as a basis for seeking proposals
  - if monitoring is to be undertaken internally, a commitment is made by managers to resource the task and the expectations and commitments are documented
  - in the evaluation and selection of any external contractor, agreements are defined for key elements of monitoring, responsibilities for data management, interpretation and storage, progress and final reporting/recommendations
  - an internal or external project coordinator/manager has taken ownership of ensuring the continuity and success of the monitoring. This role ensures the correct activities are undertaken in the right locations, appropriate stakeholders are engaged during the process, and all relevant supporting information is made available to the consultant. The coordinator reviews all draft reports and ensures they are finalised and circulated to key personnel, and that data are managed in accordance with any agreements.
- For a medium-term monitoring plan, it is important that the link is made to medium-term construction/production plans so that any change in production or infrastructure enables adjustments to be made to the monitoring programs. For example, if the annual production rate is to increase, then pre-clearing monitoring may be required over much larger areas than previously planned. There is also a need to review the findings of annual monitoring programs to determine whether there is any need to change management practices.
- Life-of-mine plans for monitoring need to be reviewed at frequencies which reflect the rate of change of the operation. In the early stages, when the rate of change may be greatest, there may be a need for an annual review of the monitoring program in the context of life-of-mine/closure planning. When the project accelerates or decelerates, there is a need to review monitoring programs frequently. For example, toward the end of a resource there is a risk that closure or handover to another operator (change of ownership) may cause a shift in the focus which means that certain information (for example, completion criteria, community impacts due to closure, socioeconomic studies of local business impacts) is needed sooner.
- For abandoned mines or mines that have suspended operations and may be in a care and maintenance phase for an extended period of time, having a record (no matter how old) of past monitoring plans, data and maps showing monitoring sites is invaluable. Such information provides a sound basis for risk assessment focused on developing a closure plan.

In summary, the key element is to ensure monitoring programs are aligned to production/construction aspects of operational planning. While many monitoring components may be defined through the ESIA process and formalised through

regulatory documents (such as licences and authorities), there are other components which are internally driven to develop site-specific methods and datasets for other purposes (for example, using water and energy more efficiently). Documentation of overall monitoring plans is essential if continuity is to be maintained between generations, as some mines have very long lives. Such plans are also helpful when there is a change of ownership to maintain the momentum of monitoring programs and minimise data gaps at critical stages.

### 3.4 Community involvement in monitoring design

Two key elements of leading practice sustainable development are the need to involve stakeholders in information exchange and decision making, and transparency. With regard to monitoring design, this requires consultation with the community. This can take place during the formal ESIA process, or on an informal basis at any stage prior to monitoring—or even during the course of the monitoring program, when the need for changes or improvements becomes apparent.

Some examples of community involvement in monitoring design include:

- consulting Indigenous communities (including Traditional Owners) on what species might be important for cultural, food, medicinal or other purposes
- discussing the design of air and water quality monitoring programs with interested members of the adjacent local community (see the Alcoa Anglesea example in Section 4.6)
- discussing land use practices with community members prior to developing a program for monitoring possible impacts of mining on current or potential land use options
- consulting members of local naturalist groups on the current or previous known presence of rare or threatened species
- obtaining local information and views on matters relating to historic and traditional cultural heritage.

Unlike environmental monitoring and compliance, the development and implementation of rigorous monitoring systems for socioeconomic impacts of mining activities is still in its relative infancy. Historically, social evaluation has consisted of community baseline studies or social impact assessments, often with a compliance or regulatory emphasis and serving as addendums to broader environmental impact assessments. Although environmental and social impact assessment guidelines frequently recommend the inclusion of socioeconomic monitoring regimes, there has been little requirement for organisations to show evidence of ongoing evaluation or rigour in indicator development, data collection or reporting.

Coinciding with the emergence of sustainable development reporting requirements such as the GRI, voluntary codes such as *Enduring value* and organisational statements on sustainable development aspirations, there is increasing recognition among leading practice companies of a need to develop rigorous and transparent frameworks for social performance monitoring. As with leading practice environmental monitoring, such frameworks are important not just for organisational reporting and compliance requirements.

Leading practice social performance monitoring should be rigorous, context driven, socially engaged and locally relevant, and should:

- provide a systematic and consistent information base that can act as a barometer of community change and development at various stages of a project's life cycle
- inform both operational and community decision making, and feed into key community investment development programs
- integrate with broader operational strategic planning and management frameworks, thereby facilitating the inclusion of community considerations in a whole-of-operation approach to sustainable development
- be inclusive of external stakeholders at all stages of the development, implementation and reporting of the framework
- engage with community aspirations for regional development and benefits transfer
- acknowledge, identify and respond collaboratively, where locally appropriate, to the broader cumulative impacts and benefits arising from mining or other local industrial activity.

### **3.4.1 Elements of a socioeconomic monitoring framework**

What to monitor, and how much to monitor, are two of the most challenging elements when designing effective social monitoring. Although typical social elements are listed in Appendix 2, there is no formula, or 'right' number, of indicators to be included in a monitoring framework. Those designing the monitoring program need to maximise the efficiency of surveys and avoid oversampling. Leading practice involving cooperation between different mining companies can help reduce this.

One model that has been successfully applied to monitoring operational impacts in Australian settings is the 'five-capitals' model of sustainable development (Meadows 1998; Porritt 2005). There are various versions of this model, which may be broadly defined around five types of capital:

- economic: the stock of financial resources available to a community
- social: networks and relationships that enable cooperation
- human: the stock of skills and knowledge of a community
- built: the physical infrastructure available to a community, including telecommunications
- natural: access to key natural resources such as land, water and clear air.

Table A2 in Appendix 2 expands these definitions. In some instances, depending on the context and dynamics of the community in question, practitioners may extend the scope of the model to include additional areas such as spiritual and political domains.

The five-capitals model seeks to bring about a balanced view of socioeconomic monitoring which recognises the potential substitutions and trade-offs that may occur across the different community domains while seeking to achieve a net positive outcome when considering the social system as a whole. In practice, the



## CASE STUDY: Evaluating the effectiveness of community partnership programs

In 2008, BHP Billiton Mitsubishi Alliance (BMA) commissioned an independent review of their Community Partnerships Program (CPP). The review was a follow-up to a study undertaken in 2005, when the CPP was in its formative stages—that study is described in the *Community engagement and development handbook* (DITR 2006).

The purposes of the 2008 review were to assess how effectively specific recommendations from the previous review had been implemented and to evaluate the overall effectiveness of individual partnership programs. The key challenge was to develop a research method to identify progress since the previous review, as well as a more robust framework that could be used to monitor and evaluate the performance of individual programs over time.

The model chosen to measure the effectiveness of the individual programs, Bennett's hierarchy, is an assessment tool based around seven evaluation categories that represent a seven-link 'chain of events' (Bennett 1975). First in the chain are inputs (1) that produce activities (2). These activities involve people (3) who have reactions (4), positive and negative, to the program activities. These people may change their knowledge, attitudes, skills and aspirations (5) as a result of participation in the program. Practice change (6) occurs when people apply their changed knowledge, attitudes, skills and aspirations to working and living. End results (7) are the outcomes from these practice changes.

Key findings from the review were that:

- The CPP is highly valued by BMA's partners.
- A great strength of the CPP is its consideration of local community needs, which had been identified using extensive community consultation in 2002.
- In terms of the individual programs, some are more ambitious than others, and the partners have varying capabilities. In spite of these differences, most partners were able to demonstrate positive outcomes from their programs.
- The one area of negative feedback related to the adequacy of the current reporting pro forma, which was regarded negatively by virtually all partners, primarily because it was not seen as containing appropriate performance measures. As one participant commented, 'It doesn't really capture the nature of our achievements'.

Feedback from BMA indicated that the company regarded the review as a valuable exercise, because it demonstrated the increasing maturity of the CPP and provided direction for its future development. BMA accepted the recommendations made in the report and intends conducting another review in the next two to three years. The company has also redesigned its reporting pro forma and received very positive feedback on the changes from community partners.

model also has the potential to facilitate a structured dialogue between a community and an operation, and may help clarify potential agreements and disagreements that can occur across and between the community and the operation.

When considering the five-capitals model, it must be noted that, like all systems, it does impose a somewhat artificial demarcation on what might otherwise be a complex social arena. Those designing the monitoring program need to determine the extent of the risk that they will not get the information they are seeking from this method, and how that risk should be addressed. Similarly, it has been suggested that the five-capitals model is constrained in its capacity to accommodate complex and shifting social conditions and that it does not adequately address the mix of power structures and influencers that form the backdrop to many communities, particularly those that might be experiencing conditions of transition.

### **3.4.2 Evaluating partnerships through social performance monitoring**

Over the past decade, there has been a significant trend within the minerals industry towards greater investment in local communities, usually through community partnership programs. Partnership programs are seen as valuable opportunities to build relationships with local communities while enhancing a company's reputation. They also help to build the knowledge base and capabilities of community groups and regional business enterprises, thereby enhancing their sustainability beyond the life of the mining operation. All of these contribute to the company's sustainable development goals and help maintain its social licence to operate.

As companies have become increasingly sophisticated in their development of corporate community partnership programs, they have recognised that it is necessary to measure and monitor the performance of these social programs as they would the performance of any other corporate investment. This means that companies are seeking methods that will enable them to collect robust and reliable performance data that can be used for performance monitoring and evaluation, is replicable and can be used to benchmark performance over time, and incorporates processes that are open and transparent to all parties. Unfortunately, there is little in the way of existing frameworks that can deliver these requirements.

Evaluating partnership performance is a complex process because it involves evaluating the effectiveness of the partnering relationship in terms of:

- the extent to which the program successfully addresses the strategic business objectives of each partner
- the ability of the partners to achieve program goals
- how effectively the partnering relationship is managed.

### **3.4.3 Monitoring framework for Indigenous communities**

Particular consideration should be given to ensuring monitoring systems adequately address the impacts of mining operations on Indigenous communities. This may be the case where an operation has a local Indigenous employment program, or where specific benefits transfer or impacts flow to Indigenous communities through formal or informal mechanisms.

Historically, the economic and development benefits that accompany mining activities have often failed to have substantial positive flow-on effects for Indigenous communities. In the past two decades, there have been moves to redress the imbalance, due to a growing recognition that the development of sustainable relationships with Indigenous communities may have mutually beneficial outcomes. Outcomes negotiated through mechanisms such as Indigenous Land Use Agreements and community investment and development funds are now providing opportunities to formalise mining company commitments to Indigenous communities and meet Indigenous development aspirations. The aim is to ensure long-term, sustainable and culturally appropriate outcomes for Indigenous people.

For these initiatives to be successful, understanding the changes that can take place in Indigenous communities affected by mining and the efficacy of engagement programs is of significant importance for both mining companies and the impacted communities. Timely, rigorous and transparent social performance monitoring has an important role to play in providing stakeholders with the capacity to influence, steer, and promote development programs in a culturally appropriate and responsive manner. Likewise, leading practice monitoring frameworks for Indigenous communities integrate, and work collaboratively with, the local Indigenous community at each stage of the development, implementation and reporting of the monitoring framework.

Guidance on Indigenous engagement and economic development may be found in the leading practice handbook *Working with Indigenous communities* (DITR 2007).

#### **3.4.4 Including communities in the monitoring development process**

Effective community engagement needs to take account of all elements of monitoring, including socioeconomic, cultural, biological and chemical/physical. There are a variety of potential mechanisms and engagement processes through which a community may have input into the design and implementation of a monitoring framework. The mechanisms are discussed at length in the leading practice handbook *Community engagement and development* (DITR 2006). Ideally, they should involve processes for community inclusion at each stage of the monitoring framework's development and implementation.

As an example, socioeconomic monitoring frameworks in the mining industry are most effective when they follow a bottom-up approach, defining criteria locally and including local aspirations, development goals, context, and the range of potential risks and/or benefits that may accrue to a community through mining activity. At the same time, these processes need to link to operational strategic and sustainable development goals. Hence, when developing and implementing a socioeconomic monitoring framework, both community input/values and operational objectives/targets need to be included.

### 3.4.5 Criteria for indicator selection

Indicators should be selected with the goal of providing a consistent, reliable and valid dataset which can be sustained over time. Ideally, indicators should comply with the general principles of:

- validity—logically measuring what they are supposed to measure
- reliability—remaining consistent over time
- simplicity—not being overcomplicated, particularly if the community is to participate in data collection
- comprehensiveness—encompassing the whole complexity likely to exist
- availability—being easy to collect
- practicality—not being onerously resource intensive (adapted from Black & Hughes 2001).

However, in a real-life operational context, where there are many competing demands on time and resources, the rigid application of such criteria can be excessively constraining. Socioeconomic frameworks therefore need to be developed with considerations of cost and availability firmly in mind. Rather than developing a suite of purpose-built indicators, it is sometimes more effective and practical to use information that is already being collected by other, preferably locally operating, agencies (for example, local environmental surveillance groups, local or state government bodies or community organisations), or can easily be generated by an operation's standard operating procedures (for example, employment or procurement data with respect to source of labour hire, or degree of local spending and benefit transfer).

Further, rather than relying solely on 'objective' quantitative measures, the inclusion of qualitative feedback from local experts or community groups, collected in a consistent and replicable format, can substantially enhance the context of the information obtained. This approach, while perhaps falling short of strict scientific standards, has the significant advantage of being practical and capable of capturing a range of community inputs and voices. Finally, using multiple indicators for each of the primary domains, or community assets, also minimises the risk of misreading or ignoring significant trends.

### 3.4.6 Monitoring for social performance over project stages

As indicated elsewhere in this handbook (sections 3.2 and 3.3) and other handbooks in this series, planning and development for an effective monitoring framework should occur as early as possible in a project's life cycle. The earlier an operation is able to establish the regional socioeconomic starting point, or baseline, the more that operation will be able to clearly delineate, track and understand the changes that take place in a community as a result of the project.

It may be necessary over the course of a project to adjust a monitoring framework and enable indicators to take into account shifts in operational circumstances. Examples of these can include major transitions from construction to operations; expansion programs; changes in workforce delivery mechanisms, such as the

## **CASE STUDY: Monitoring to provide a safe site for heritage tourism and heritage conservation**

The Mount Morgan Mine located in central Queensland was the largest gold mine in Australia in its time; it produced 7,500,000 ounces (roughly 250 tons or 13 cubic metres) of gold, and 360,000 tons (or 40,359 cubic metres) of copper. Significant heritage value is attributed to the physical legacy of the complex, which represents a wide range of innovative and historic mining technologies, evidenced by both intact and ruinous structures and the mining landscape, with elements surviving from the whole period of mining between 1882 and 1981.

A significant part of the historic 184 hectare mine site has been listed in the Queensland Heritage Register under the *Queensland Heritage Act 1992* and in the Register of the National Estate of the Australian Heritage Commission. In order to conserve the industrial heritage values of the mine, a conservation management plan, interpretation plan and tour guide resource manual, in line with the Burra Charter (Australia ICOMOS 1999) were developed to establish leading practice heritage management at the site.

The conservation management plan included a one-off assessment of the structural stability of 14 significant structures on site (Austral Archaeology Pty Ltd 2001, 2002). This helped Queensland Mines and Energy (QME, now a part of the Department of Employment, Economic Development and Innovation) to prioritise the funding of works based on both heritage significance and the urgency required to stabilise the structures and to arrest decay.

The interpretation plan focused on how the site can be thoroughly explained to visitors in an interesting manner. An example of this is the fireclay caverns, which contain significant Early Jurassic dinosaur footprints. Interpretive signage was installed, and safety assessments led to the development of an entry structure and construction of walkways. Monitoring of the geotechnical stability of the caverns continues.

QME regularly uses these heritage management documents when evaluating the potential use of areas or buildings on the mine site, as well as undertaking monthly heritage inspections to monitor and document the structural stability and any additional observations of the heritage structures. The project's risk register is reviewed at regular intervals and updated, particularly if storm or other damage occurs to buildings or repairs or stabilisation works are undertaken. The risk register enables the condition of infrastructure to be kept up to date, with the aim of minimising risks to visitors and personnel on site while enabling QME to

*(continued)*

prioritise works. Liaison with the mine tour operator ensures the communication of any changes to access routes due to safety considerations.

Tour operations are important for the local community, as a source of employment and town pride. They provide a vital link between mine-based and town-based heritage trails, to fully integrate the interpretive experience (funded by the Queensland Heritage Trail Network, local government and other sources). About 4,000 tourists visit the mine each year through the tours. In addition,



**Visitors admire the Early Jurassic dinosaur tracks on the sandstone ceiling of the fireclay caverns, once a muddy lake edge overlaid with coarser sediments. Safety risks were addressed by implementing advice from a geotechnical assessment and constructing a walkway. Source: Sam Pegg, Department of Employment, Economic Development and Innovation.**

QME hosts another 150 visitors each year for technical, education and training purposes. The Mount Morgan Tourism Development Plan was created to further capitalise on and develop mining heritage tourism in Mount Morgan.

The initial heritage studies provided a fundamental context, delineating long-term objectives for heritage conservation so that ongoing monitoring and management programs can take place.

introduction of fly-in-fly-out; or unplanned contraction. For projects with a long life, say 25 years or more, or operations established in a greenfields environment, the indicators of high importance during construction may diminish in importance as the operation matures and the community adjusts to changed circumstances. While the

fundamentals of a monitoring framework may remain intact for the life of the mine, elements of a framework must be adjusted where necessary, to accommodate shifts in project life cycles, as well as expansions and contractions.

### **3.5 Elements of the monitoring program**

Elements of mining project monitoring programs can be broadly categorised into environmental, social, occupational health and safety (OHS), and routine operational monitoring. Typical elements of environmental, social and OHS monitoring, and indicative frequencies of monitoring throughout all stages of project development (exploration/feasibility, construction/operations/expansions, closure and post-closure) are outlined in Appendix 2. Routine operational monitoring is not specifically addressed in Appendix 2, although some operational monitoring parameters, including water balance, ore and waste production rates and composition, have direct relevance to other aspects of monitoring such as discharge water quality and acid and metalliferous drainage.

As noted in Section 2.1.2, each project will have specific regulatory monitoring requirements. However, the incorporation of additional monitoring parameters and performance evaluation criteria is essential to the identification and proactive management of environmental, social and OHS issues during the project life. Leading practice methods go beyond regulatory requirements and aim to investigate high-risk aspects, quantify and mitigate impacts, develop solutions and assess the success of control measures. As noted in Section 3.1, a risk-based approach is recommended to ensure that, regardless of the size of a mining operation, site-specific monitoring programs incorporate appropriate monitoring elements, parameters, frequencies and applicable performance criteria on which to assess the monitoring data.

Appendix 2 should be considered 'indicative' of a leading practice monitoring program, and is intended to provide a basis for establishing a detailed program that is relevant to site-specific sensitivities and the nature and scale of potential impacts. The elements outlined in Appendix 2 are not necessarily exhaustive for all mining projects, nor is each element and suggested frequency of monitoring relevant to all projects.

Further guidance on the identification of suitable monitoring parameters, frequencies and performance evaluation criteria is provided in other leading practice handbooks.

### **3.6 Research and investigations**

During the phases of a mining project, at some point a situation may emerge where cost-effective methods of assessing and minimising impacts, restoring environmental values, or rehabilitating degraded sites are not well understood. A major reason for this is that all sites are different, and while the approach and process used by other projects may have developed leading practice methods of addressing knowledge gaps, specific characteristics of the current project site may require modifications to the established management procedures.

This requires a leading practice approach, namely, a willingness to conduct research, trials, or whatever investigations are necessary to assess and manage impacts to an extent acceptable to all stakeholders.



## CASE STUDY: Monitoring to improve rehabilitation quality

Alcoa operates two bauxite mines in the jarrah forest of south-west Western Australia. Approximately 600 hectares of forest are cleared, mined and rehabilitated each year. The published objective of the rehabilitation is 'to restore a self-sustaining jarrah forest ecosystem planned to enhance or maintain conservation, timber, water, recreation, and other forest values'.

The success of this rehabilitation is assessed by using several different monitoring systems, each targeting a different aspect of rehabilitation quality. To fulfil the conservation component of Alcoa's rehabilitation objective, it is considered essential to restore the floristic diversity of the forest to rehabilitated areas. Hence a botanical richness target has been developed: 'The average number of Indigenous plant species in 15-month-old restoration is 100 per cent of the number found in representative jarrah forest sites, with at least 20 per cent of these from the recalcitrant species priority list'. Recalcitrant species are typically fire resprouters that are common in the unmined jarrah forest but are difficult to re-establish and are historically absent or under-represented in the restored mined areas. The resprouters by definition give the jarrah forest a high resilience to natural disturbances, particularly fire and grazing, and hence are a crucial component of the ecosystem.

Progress toward this target is monitored when rehabilitated areas are 15 months old, using approximately 100 randomly located 80 square metre plots. At fixed intervals (6, 15, 30 and 50 years of age) a subset of the monitoring plots is repeat monitored, which provides long-term data on plant succession and vegetation development. Identical plots are monitored in the unmined jarrah forest to provide reference site data.



The photograph shows a 15-month old rehabilitated bauxite pit being monitored. Each year approximately one hundred 80 square metre plots are assessed.

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The pattern of plant succession in rehabilitated bauxite mines tends to follow the 'initial floristic composition' model, where the first plant species to establish on the sites dominate the vegetation for at least several decades. Long-term monitoring has shown that species richness shows little change over time and, in fact, can decrease as short-lived annual species and disturbance-opportunist species, such as the acacias, senesce over the first few decades. Accordingly, Alcoa's strategy is to restore the highest level of species richness possible in newly rehabilitated areas.

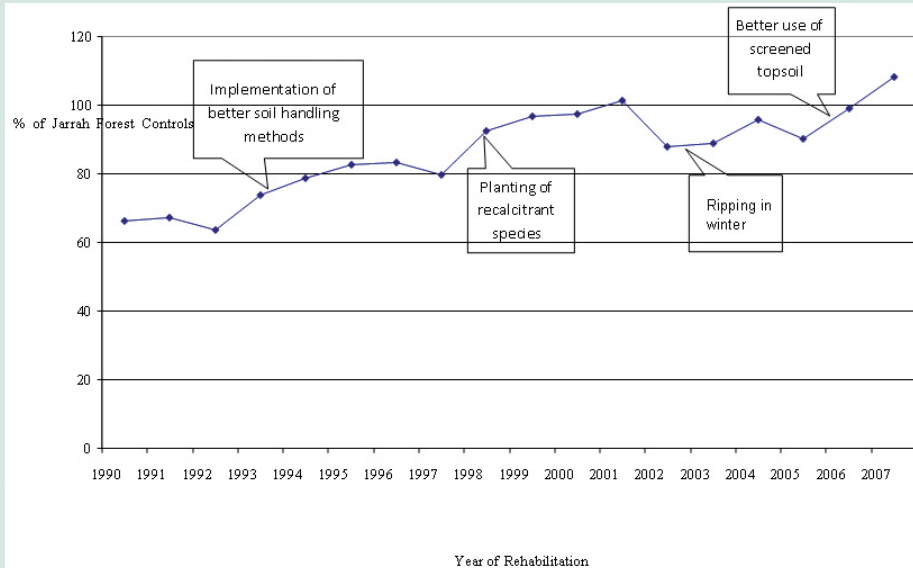
In rehabilitated areas, plant species establish from three main sources: the natural seed in the returned topsoil, seeds that are collected and broadcast onto rehabilitated areas, and planted greenstock (mostly the recalcitrant species described previously). Natural recruitment by native species is slow; if areas are left bare, they are usually colonised by exotic weeds which have strong dispersal and recruitment characteristics. Research has shown that correct soil handling practices optimise the return of native species from the natural soil seed bank, which can contribute 70 per cent of the species richness of a restored bauxite pit. Hence the quality of the rehabilitation establishment procedures is closely reflected by the number of native plant species that establish in the first two winter seasons; in other words, better rehabilitation procedures lead to higher native plant species numbers.

For example, carrying out the final ripping operation during dry soil conditions in summer (the dry season in the jarrah forest ecosystem) results in increased numbers of plants and species establishing. By contrast, ripping the sites well after winter rains have commenced significantly reduces the number of plant species by killing the newly germinating seedlings. In addition, the natural soil seedbank in summer is double the density of the winter soil seedbank, so summer is by far the best season to utilise this important resource.

Each year the data collected during the 15-month monitoring program is compared with records of rehabilitation activities, which are stored on a geographic information system (GIS). The GIS includes the original source of the topsoil, the date of clearing of the source site, the date of removal of the topsoil, whether the topsoil was stockpiled or directly returned to a rehabilitated area, the location and duration of stockpiling, the date of respreading of the topsoil, the date of final contour ripping, and the date of seed application. This enables rehabilitation practices which lead to high returns of plant species, as well as those that result in poor rehabilitation, to be identified.

At a feedback session held each year, mine planners, environmental staff and rehabilitation operations staff review the monitoring results in relation to rehabilitation practices and discuss improvements to rehabilitation practices. Approved enhanced practices are subsequently implemented. This intensive monitoring and feedback process has enabled Alcoa to measure progress and make improvements over an 18-year period.

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The graph shows the 15-month monitoring results for newly rehabilitated areas from 1990 to 2007. Identical plots are assessed in unmined forest controls, and the mean native species richness of these unmined forest controls is nominally set as the 100 per cent improvement target. The graph shows the effects of several different rehabilitation practices on the monitoring results that are obtained each year, including the decrease in plant species richness due to winter ripping in 2002-03. Source: John Koch, Alcoa of Australia.

Baseline and subsequent surveys can identify the need for research and investigations. For example, these may reveal the presence of:

- flora species for which propagation methods are not known
- fauna species whose habitat requirements are not well known
- specific flora-fauna interactions that are not well understood but may be important for ecosystem sustainability
- availability and characteristics of topsoil that may require specific remediation or other treatment to ensure successful revegetation
- overburden material characteristics that require specific procedures to ensure the successful construction and long-term stability of waste dumps and/or tailings storage facilities
- community subgroups with differing economic and land use requirements and aspirations
- gaps in local skills, education, or other employment-related capacities
- limited business diversity which may restrict opportunities for economic benefits to flow to the local community.

Ongoing monitoring through all phases of a mining project can also reveal problems that need addressing, for example:

- problems relating to establishment or growth of rehabilitation plantings
- unexpected water quality impacts arising from specific site characteristics and environmental values
- difficulties associated with managing dispersive soil material, together with characteristics that may require different handling procedures, such as variable soil salinity
- inappropriate distribution of financial benefits from the mine throughout the community
- social structures that do not represent generally accepted social norms in terms of human rights, women's rights, vulnerable groups and the like.

In almost all cases, it is far preferable to discover issues that require further investigation earlier rather than later. This gives more time to develop solutions, which may reduce the duration or extent of impact. With regard to rehabilitation, identifying and addressing problems can decrease the overall area rehabilitated using sub-optimal methods. Good research or trials can result in more cost-effective management, for example, by discovering better ways of doing things, and fixing rehabilitation problems while mining equipment is still on site.

A commitment to leading practice monitoring and, where necessary, to research and investigations, can result in significant improvements in overall environmental performance. A good example of this is the mine rehabilitation program conducted by Alcoa in Western Australia, which has reached its current high standards through a process of continuous improvement over a period of more than 30 years (Koch 2007a, 2007b; Grant et al. 2007; Majer et al. 2007; Nichols & Grant 2007).

While monitoring can identify the need for research or trials, in some situations, optimal methods of conducting surveys or monitoring may not be known, and may require research. A good example of this is the work commissioned by the Australian Centre for Mining Environmental Research to investigate methods of monitoring water quality in ephemeral stream and lake systems (Smith et al. 2004).

Some issues may require detailed research programs, whereas others may be resolved using simple field trials such as those used to fine-tune fertiliser and seeding rates in rehabilitation programs. Depending on the work involved, and the skills and resources required, research and investigations may need to be carried out in-house by external consultants or universities or other research institutions.

It is important for companies to develop research and development plans compatible with Industry Research and Development Board requirements, in order to gain the benefits of the tax incentive scheme while devising solutions to site-based challenges.





## 4.0 MONITORING: IMPLEMENTATION

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### Key messages

- Leading practice monitoring is essential for achieving consistent good performance outcomes and continuous improvement.
  - Community participation is a decisive element in the design and implementation of leading practice socioeconomic and environmental monitoring.
  - Consistent, accessible and transparent data management systems are critical for ensuring quality assurance and quality control standards are maintained and data can be utilised to the maximum advantage of all involved with, or affected by, the project.
  - Monitoring, auditing and research all play a critical role in the development of achievable completion criteria.
  - Leading practice monitoring systems are regularly reviewed and revised to take into account changes in mine planning, improvements in monitoring technology, and other aspects.
  - Reporting systems for monitoring and auditing must be accurate and timely, and address the information needs of stakeholders. Feedback from monitoring programs should inform operational planning and decision making.
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### 4.1 Overview of leading practice monitoring procedures

This chapter describes what are generally accepted as leading practice monitoring procedures. Inevitably, there is some overlap with both routine monitoring and more 'cutting edge' procedures. However, it should be recognised that mining companies identified for leading practice inevitably fulfil their routine monitoring commitments as required, on time and to the highest practicable levels of quality control, and treat even routine monitoring as an opportunity for learning and achieving continuous improvement.

Sometimes, there is not a clear demarcation between cutting-edge procedures and routine leading practice. However, all procedures described in this chapter are believed to be practicable and cost effective in the situations in which they have been applied.

The chapter focuses on the key risks and interactions with the environment and communities that need to be addressed by monitoring for performance evaluation. Further details are provided in Appendix 2 and the leading practice *Managing acid and metalliferous drainage, Mine closure and completion* and *Mine rehabilitation* handbooks (DITR 2007b, 2006a, 2006b).

## 4.2 Open-pit monitoring

Open-pit operations involve both the creation of a void and the placement of waste and subeconomic materials on the adjacent ground surface. Monitoring of the waste rock types removed from the pit and their selective placement in dumps is part of an effective management plan for acid and metalliferous drainage.

Other key aspects requiring monitoring are geotechnical stability and safety, groundwater ingress and drawdown, and groundwater quality. Geotechnical stability and safety are monitored by daily inspections by qualified geotechnical personnel, controlling access to the pit, and slope stability monitoring equipment such as radar scanning and survey prisms to monitor wall movements. Groundwater ingress is monitored and controlled by in-pit pumping, and groundwater drawdown is monitored by piezometers around the perimeter of the pit and beyond. Boreholes are sampled to monitor groundwater quality.

Prior to mining, the impacts on water of creating an open pit are quantified using various modelling tools, as described in the leading practice handbook *Water management* (DRET 2008b). Interactions between surface and groundwater and the void are based upon assumptions about the staged development of open pits and adjacent landforms scheduled within the life-of-mine plan. These modelled parameters enable pit dewatering requirements and associated impacts to be predicted prior to mining, so that mitigation measures can be planned and implemented.

As a consequence of the limitations of modelling, leading practice requires the model, as well as the dataset and assumptions which are used as a basis for modelling, to be verified and amended according to data collected during the operational phase (Kuipers et al. 2006). Modelling should not be used as a once-off tool with initially limited input data. To assist design and planning in the pre-mining phase, modelling should instead be regarded as an iterative process whereby monitoring should focus on the collection of data to which the model is particularly sensitive. This will enable the accuracy and validity of the model to be continually improved.

This goes beyond estimating likely water inflow rates, to include predicting water quality based on key geochemical characterisation parameters, as well as monitoring the effectiveness of various control measures (such as seepage barriers). Where mines are close to water resources with identified beneficial values (for example, for potable supplies, grazing and ecosystems), additional attention is required.

Post-mining objectives for the open-cut pit will also influence what key investigations and data gathering are required during the operational phase. Operational monitoring, efficiently combined with life-of-mine void management issues, will enable timely and effective closure strategies to be developed in consultation with regulatory and community stakeholders. Questions to be considered may include:

- Will the final water quality in a flooded open pit be sufficient to permit access and use by others for grazing, recreational or urban use?
- How will the water levels and fluctuations impact pit wall stability?
- Will there be impacts on nearby significant rivers, during or after mining, and could valuable water resources drain to the void and become contaminated rather than remain accessible and usable to downstream and adjacent water users?



- Could contaminated water from a flooded pit contaminate adjacent ground and surface water systems?
- Will dewatering or stream diversions around voids impact groundwater-dependent ecosystems?

After mine closure, geotechnical stability and safety must be maintained and groundwater recovery addressed following cessation of dewatering. Quality of groundwater should be readily predicted using data gathered during operations and refined models. Groundwater monitoring will be needed to verify predictions. Geotechnical stability is ensured through regular inspections by qualified geotechnical personnel, and safety is ensured by restricting access to the pit using appropriate bunding and fencing. Groundwater recovery and quality are monitored by piezometers and boreholes respectively, around the perimeter of the pit and beyond.

## 4.3 Waste rock dump monitoring

### 4.3.1 Hydrology of surface waste rock dumps

Waste rock typically emerges from an open pit in a relatively dry condition. Once placed in a surface dump, hydrological processes are influenced by:

- rainfall infiltration
- the magnitude and intensity of rainfall
- the height of the waste dump
- the nature of the waste rock.

Waste rock dumps have the potential to generate base seepage to the underlying foundation and to the toe of the dump. The seepage is likely to be contaminated. As the dump wets up due to rainfall infiltration, the rate of base seepage will increase.

Eventually, the waste rock will achieve a degree of saturation, at which time further rainfall infiltration will be matched by base seepage; this is known as 'continuum breakthrough'. Ideally, an effective low-percolation cover should be placed over the dump (or parts of the dump) as soon as possible, preferably as part of a progressive rehabilitation strategy before the state of continuum breakthrough is reached, so that base seepage rates remain low.

A foundation of relatively high hydraulic conductivity will allow base seepage to infiltrate, while a foundation of relatively low hydraulic conductivity will cause flow along buried natural or constructed surface drainage channels to a low point where it will emerge at the toe of the dump. In most cases, a combination of foundation and toe seepage will occur, with seepage to the foundation directly underlying the footprint of the dump likely to be dominant. In order to design control measures to manage this water, and assess the performance of these measures, monitoring is required before, during and after construction of dumps to enable prediction of hydrological behaviour.

### 4.3.2 Geochemistry of surface waste rock dumps

Monitoring must verify the geochemical characteristics and model assumptions which guide waste rock dumping plans in order to continue to protect adjacent water values throughout the life of the operation. Contaminant load predictions made during exploration can be checked and adjusted and more complete operational datasets can be used to plan rehabilitation (and determine whether covers are required) (see Appendix 2).

Where covers are required, cover designs should integrate what has been learned from monitoring both waste rock hydrology and geochemistry, and the covers should be monitored for stability and performance.

### 4.3.3 Water monitoring of surface waste rock dumps

The quantity, rate, quality and fate of surface runoff and base seepage from a surface waste rock dump are all important in assessing potential environmental impacts. The balance between runoff and infiltration will depend on the rainfall regime, with the conditions present in the monsoonal tropics being very different to those in semi-arid or southern temperate zones.

In view of the relative difficulty of obtaining accurate and direct measurements of rainfall infiltration into, and base seepage from, waste rock dumps, monitoring should be directed at understanding the overall water balance and wetting-up over time. Automated weather stations installed on waste rock dumps provide useful data for the water balance. These stations should be equipped with a full range of metrological sensors, including solar irradiance and evaporation pans, so that actual evaporation can be calculated and estimates can be made of rainfall infiltration and runoff. The volume of surface runoff should be measured in flumes located in surface runoff drains to provide this component of the overall water balance, and provide a cross-check of the infiltration estimates.

Seepage to the foundation will often result in groundwater mounding, which should be monitored by means of borehole piezometers around and beyond the waste rock dump footprint. Borehole sampling should be employed to monitor groundwater quality.

Following the closure of a surface waste rock dump, it is necessary to monitor rehabilitation to assess whether objectives have been met, for example, targets for erosion due to rainfall runoff, dust generation by wind, the performance and stability of drainage works, and vegetation establishment and sustainability of land uses. Further details are provided in the *Managing acid and metalliferous drainage, Mine closure and completion* and *Mine rehabilitation* handbooks (DTR 2007b, 2006a, 2006b).

Where geomorphic stability and sustainable land use are important, monitoring of erosion on slopes and the water quality impacts of suspended solids flowing from waste rock dumps or sediment control dams is likely to be needed.

Monitoring seepage as well as surface runoff water quality and volume is also crucial for understanding risks to wildlife, other animals and communities. Fauna often interact with, or drink from, seepages or soaks at the toe of waste rock dumps, seepage channels and containment ponds. Risks to wildlife are a function of the extent of interaction, species behaviour, and water quality. Simple frequent

## CASE STUDY: Erosion monitoring for stable landforms

As for all monitoring activities, the key requirement for monitoring erosion is to ensure that the data obtained provide the precise information needed by the site. In some instances, it may be sufficient to demonstrate that erosion rates are declining. In others, there may be greater concern about potential off-site impacts.

Minara Resources Ltd operates the Murrin Murrin Nickel Operation in the north of the Western Australian goldfields. Initial rehabilitation works conducted at the site on constructed landforms showed good vegetation establishment, but high rates of erosion.

Consequently, the site engaged expert consultants to design landforms with lower erosion potential. The water erosion prediction project model (WEPP) was chosen to provide erosion simulations for design purposes. This model requires both complex soil erodibility data and a range of assumptions with respect to landscape condition and performance. For that reason, there was considerable interest in obtaining erosion data from constructed landforms to further refine the modelling process and generate even more cost-effective landform designs.

Therefore, the erosion monitoring objectives identified were:

- to demonstrate that erosion rates are consistent with site targets
- to enable validation and more precise calibration of the erosion modelling used in landform design at the site, thereby enabling continuous improvement in the design process.

For a range of designed concave slopes, measurements of rill frequency and volume were used to estimate cumulative erosion on landforms constructed in 2004 and 2005. Those measurements were compared with predictions of erosion based on the original design simulations. Actual erosion potential for the periods of interest was assessed by using data on actual rainfall to provide a comparison against predicted long-term averages. Calculated erosion potential for the periods of interest was found to be considerably higher than the predicted long-term average, illustrating the importance of considering actual rainfall records when assessing measurements of erosion.

In general, cumulative erosion measured in late 2008 showed good agreement with calculated erosion potential. Of great value was data collected in situations where flow patterns, soil condition and/or landform construction clearly did not match the assumptions used in the initial design process. Those data were used in evaluating the accuracy of the initial design assumptions.

In one or two cases, the observed variations will probably lead to slight changes in construction and rehabilitation methods, rather than refinement of the modelling process. In general, the observations made during measurement of rill volume were extremely useful, demonstrating that data without associated interpretation or qualitative observation and verification are of significantly reduced value.

*(continued)*

Landform	Location	Potential cumulative erosion since construction (t/ha)	Measured cumulative erosion since construction (t/ha)
2/3	Upper slope (not corner)	37.4	28.3
	Lower slope (below tree debris)	37.4	31.9
7/2 concave	Upper slope	37.4	0
	Lower slope	37.4	0
7/2 back	Upper slope (not corner)	30	30.1
9/4 west <sup>a</sup>	Upper slope (30 m from crest)	100-150	102.5
	Upper slope (20 m from crest)	100-150	156.6

a A landform not constructed to specification and expected to exceed design erosion rates.

The erosion monitoring undertaken at the site has provided:

- validation of the landform design process used
- confidence in the stability of existing landforms that have been constructed to specification
- refinement and improvement in the design process
- changes and improvements in landform rehabilitation methods.

This has led to changes to landform design, including the elimination of flow-concentrating structures such as berms, more effective containment of runoff on the tops of the landforms, and use of computer simulations of runoff and erosion to develop lower-gradient concave slopes.

wildlife monitoring regimes may be required, complemented by monitoring seepage chemistry, to gain an understanding of ecosystem sensitivity to key parameters.

It is also necessary to monitor sediment or seepage interception dams to ensure they capture the water they have been designed to intercept and do not collect other clean waters, and have sufficient capacity over the life of a project to perform as required. Water quality in streams and natural water bodies downgradient of seepage areas also requires monitoring to assess downstream risks to aquatic fauna and flora. Stream conditions and diversity and abundance of biota change considerably through the seasons; therefore, seasonal monitoring programs may need to be implemented.

Ecotoxicology evaluations enable the aquatic impacts to be assessed. Effective monitoring can also distinguish between chronic and acute impacts and help to evaluate the performance of landforms and water management systems.

Wetland filters, if used as a treatment of runoff water with low-level contamination and suspended solids or tertiary treatment of waters discharged from a water treatment plant, need to be monitored to ensure that they can manage and treat water at the rates required and the water they release meets water quality requirements.

### **4.3.4 Monitoring of in-pit waste rock dumps**

For an in-pit waste rock dump located in a pit that will not ultimately be flooded with water (for example, a groundwater sink in an arid area) the monitoring-related issues are essentially the same as for a surface waste rock dump. However, in the event that the pit will be actively or passively flooded at closure, there are specific monitoring requirements that will need to be addressed in relation to implications for final water quality in the flooded pit.

For example, if monitoring of waste rock quality indicates a significant propensity to generate very poor water quality seepage, it may be beneficial to consider capping the dumps as soon as possible to mitigate this process. If this is not done, the consequences could be a serious negative impact on future water quality. At the very least, monitoring of seepage will be required to provide input into predictive modelling of the chemical limnology and water quality of a future pit lake. Further details on assessment and monitoring of seepage water quality are provided in the *Managing acid and metalliferous drainage, Mine closure and completion* and *Mine rehabilitation* handbooks (DITR 2007b, 2006a, 2006b).

## **4.4 Tailings storage facility monitoring**

### **4.4.1 Hydrology of surface tailings storage facilities**

Surface tailings storage facilities (TSFs) generate the highest rates of base and/or wall seepage and groundwater mounding during operation, due to the large volumes of water discharged with the tailings. In dry climates, the volume of tailings water discharged will be many times the volume of rainfall. The actual rates of base seepage generated during operations will depend on the:

- ratio of solids to water when tailings are discharged
- particle size distribution of the tailings and inter-particle bonds
- rate of production of supernatant water
- rate of removal of supernatant water
- superimposed incident rainfall and rainfall runoff (clean runoff should be diverted so it does not enter the TSF) (Williams & Williams 2007).

By understanding the key factors influencing the hydrology of TSFs it is possible to plan appropriate monitoring programs.

Post-closure, the tailings will desiccate at the surface and drain down to an equilibrium moisture content. Water input will be limited to infiltrating incident rainfall. To minimise the volume of infiltrating rainfall, surface water should be shed

from the surface by appropriate surface contouring and design of drainage systems. In a dry climate, the tailings may become sufficiently well desiccated that any rainfall infiltration and ponded water will re-evaporate and/or simply rewet the dried-out surface layer. In higher rainfall regimes, the establishment of a vegetated cover over the tailings can maximise evapotranspiration and hence minimise net infiltration and the potential for ongoing seepage.

Monitoring of physical consolidation (including draining and drying) of tailings during the life of the TSF enables prediction of the final strength of the tailings surface in order to design covers or plan the types of equipment the tailings surface can safely support during rehabilitation.

The fate of the seepage from a surface TSF will depend on the relative permeabilities of the tailings at the base of the storage, the foundation beneath the tailings, and the TSF embankment. If the hydraulic conductivity of the tailings mass is substantially less than that of the foundation, any seepage will report to the foundation. Conversely, if the hydraulic conductivity of the tailings is substantially greater than that of the foundation it is likely there will be seepage from the toe of the tailings impoundment. If the base tailings and/or foundation and the embankment all have low hydraulic conductivity, more water will remain entrained within the tailings.

Surface expressions of seepage can quickly attract wildlife, particularly in dry environments. Surface seepages and soaks also often contain lush vegetation that attracts more wildlife. The water quality of seepages and soaks needs to be assessed to indicatively identify risks to wildlife, for example, from elevated cyanide concentrations. The lack of observed carcasses is not necessarily indicative of lack of impact or risks to wildlife, because nocturnal scavenging wildlife habitually remove carcasses. Monitoring wildlife impacts is difficult, but monitoring water quality of seeps is much easier and should form the basis of a frequent and simple monitoring regime of soaks and seepages. If water quality suggests a possible risk to wildlife, then further investigations into the extent of wildlife impact are warranted.

#### **4.4.2 Geochemistry of surface tailings storage facilities**

Monitoring of tailings geochemistry during the life of a TSF, as well as water quality of intercepted seepage and monitoring bores, enables the hydrological performance of a TSF to be evaluated.

Cover designs for TSFs should integrate what has been learned from monitoring and modelling of both the hydrology and the geochemistry of the tailings to achieve post-mining land use objectives. Contaminant uptake by plants may also need to be monitored to define potential impacts on grazing animals or humans eating bush food.

#### **4.4.3 Stability and water monitoring of surface tailings storage facilities**

The stability of a tailings storage facility is most critical during its operation. At this stage, the tailings are least consolidated and least well desiccated; ponded surface water is likely to reach its highest level; freeboard is likely to reach its minimum level; the phreatic surface is likely to be at its highest level; and temporary spillways may be in place. Hence, during its operation, monitoring and inspections of the stability of the TSF embankments are of key importance.

Monitoring to ensure geotechnical stability should include the use of piezometers within the embankments and deposited tailings against them, to record the phreatic surface, and within settlement monuments to record embankment deformations. Inspections should focus on critical embankment sections. They should identify seepage points, particularly those that are elevated on downstream embankment faces; obvious signs of embankment deformation or erosion; ponded water against sections of the embankment; and the condition of emergency discharge spillways.

In relation to seepage monitoring, an automated weather station should be installed on the TSF embankment. The volume of tailings water input to, and returned from, the TSF should also be monitored to provide the data needed to calculate overall water balance. The volume and quality of base seepage should also be monitored, particularly from low points around the TSF toe, since this reports directly to the surrounding surface catchments and into the foundation, where groundwater resources may be impacted. A TSF may have a seepage collection trench along the outer foot of the embankment with wells installed with pumps to return the seepage to the TSF. Monitoring of the quality and volume of this seepage is essential. Borehole sampling should be employed to monitor groundwater quality upstream and downstream of the TSF.

Rehabilitation objectives and monitoring of the TSF during operations will determine whether rehabilitation can be undertaken directly into the tailings or whether a cover is required. Once tailings deposition ceases and rehabilitation is undertaken, it may be necessary to monitor erosion loss due to rainfall runoff, dust generation by wind, the stability of drainage and spillway works, the time series evolution of seepage water quality and vegetation establishment and sustainability (see Appendix 2). Further details are provided in the *Tailings Management, Mine Closure and Completion* and *Mine Rehabilitation* handbooks (DITR 2007c, 2006a, 2006b).

Many wildlife species, such as *Microchiroptera* bats and waterbirds, use TSFs as wetlands where they seek food, water and resting sites. The solution and slurry quality of TSFs can be poor, and wildlife exposure to such solutions can be, but is not necessarily, detrimental. Again, a lack of carcasses does not necessarily indicate there is no risk to wildlife, as continuous deposition of tailings slurry often buries carcasses, and scavengers can remove them. Wildlife monitoring regimes for TSFs should be established, and can be simple and inexpensive to implement. Further details are provided in the *Cyanide management* handbook (DRET 2008a).

#### **4.4.4 Monitoring of in-pit tailings storage facilities**

While TSFs located below natural surface levels in disused open pits are unlikely to generate surface seepage, there are specific issues that need to be addressed and monitored for this type of tailings disposal. In particular, the composition of process solutions needs to be monitored through time to provide input to groundwater models that are used to predict the extent of interaction of the porewater in the deposited tailings with the surrounding groundwater flow field. The other critical parameters that need to be measured relate to the consolidation potential of the tailings, since this will determine the final settled level and hence the depth of an ultimate pit lake, the depth of the final tailings surface below ground level, or the volume of backfill required in the event that the pit is to be backfilled to original ground surface. Further



details are provided in the *Tailings management, Mine closure and completion* and *Mine rehabilitation* handbooks (DITR 2007c, 2006a, 2006b).

#### **4.4.5 Monitoring of heap leach piles**

Monitoring required for heap leach piles is similar to that required for tailings dams and waste rock dumps. Physical stability and leachate containment is the focus of operational monitoring. For closure planning, monitoring will need to verify that the heap leach piles are able to be rehabilitated in place once mining and processing cease, or that the materials will need to be returned to a mine void.

#### **4.4.6 Monitoring of contaminated land**

Hydrocarbons and processing reagents which have potential wider impacts on the environment must be monitored as part of a contaminated land assessment and remediation strategy during operations and, if required, should be part of a decommissioning plan.

### **4.5 Monitoring issues specifically associated with radioactive minerals**

Globally, uranium mining activities are expanding to help meet the increasing demand for supplies of raw material for use in electricity generation. Australia has the largest proportion of the world's identified uranium resources, including the largest known single deposit, which is at Olympic Dam in South Australia. Specific radiation-related issues are associated with uranium mining, and with some other mining operations that deal with naturally occurring radioactive materials, such as mineral sands, phosphates, rare earths, oil and gas.

Uranium mining is usually carried out by conventional methods in open cut and underground workings. It is basically a form of metalliferous mining. The most significant risks and issues associated with potential environmental impacts from uranium mines are rarely associated with radioactivity. All environmental protection rules and monitoring procedures required of heavy metal mines need to be applied, as well as those specifically related to the radiological aspects of the operation. It also needs to be understood that the community generally maintains an extremely close watch on uranium mining operations; therefore, monitoring programs would generally be expected to be nothing less than leading practice.

In these circumstances, monitoring at a uranium mine needs to pay special attention to radiochemical and radiological parameters in addition to the standard suite of physiochemical monitoring parameters that are collected for metal mines. Such radiochemical and radiological monitoring is recommended by international and Australian guidelines and codes of practice, irrespective of the fact that the most significant risks and issues associated with uranium mines in Australia are rarely associated with radiological exposure (in contrast to the situation in very high-grade underground mines in Canada).

Actual radiation protection issues are primarily related to workforce OHS matters for persons who may be exposed to radiation in the mine and processing areas for extended periods. These exposures are monitored through radiation safety plans that are required by regulatory authorities and refer to international safety standards and

limits that are incorporated into Australian law. Environmental radiation monitoring is usually undertaken at the boundaries of working areas to ensure that fugitive dust and atmospheric emissions, if present, are below the internationally agreed limits and are kept 'as low as reasonably achievable'. The elements of such monitoring programs are listed in Appendix 2.

From an environmental monitoring perspective there are specific social and environmental issues which need to be considered. For example, food chain issues may be of concern if radiation levels of the post-mining landform are above previous background levels. Baseline studies are essential for understanding the naturally occurring pre-mining radiological situation. Cover design and/or selective placement of materials with low radioactivity levels are methods used to address food chain issues during the operational and post-rehabilitation phases. This ensures that the levels of radionuclides in both aquatic and terrestrial bush foods are not an issue with respect to the total annual dose that may be presented to a member of the general public (including local Indigenous people, recreational anglers and the like). Post-rehabilitation monitoring should be aimed at understanding aspects such as these, and facilitating management of OHS issues for members of the public and other land users, and for flora and fauna.

Current International Commission for Radiological Protection recommendations that have been adopted in Australia specify that the total exposure of the general public to radiation throughout the operation of the facility, as well as from a remediated uranium mine site, should be no more than 1 millisievert per year above pre-mining levels. To be able to demonstrate that this target has been achieved by the remediation practices that have been implemented, it is essential to conduct a robust measurement of the pre-mining radiological condition.

It is important to note that uranium is increasingly being recovered by a process known as 'in situ leach' or 'in situ recovery', where a leaching solution is injected into a confined aquifer located in a uranium-bearing permeable rock formation then pumped through the rock to dissolve uranium as the solution returns to the surface. The uranium-enriched solution is subsequently treated to recover uranium. There are no tailings disposal facilities or waste rock stockpiles associated with such mines, but environmental monitoring of the groundwater in, and adjacent to, the mining area is obviously of extreme importance, especially to be able to ensure that there are no excursions of uranium mining solution away from the site. There are also issues associated with disposal of radioactive residues from some parts of the process, including evaporites containing radium. Disposal sites for such materials need to be included in the monitoring program. The in situ recovery process is essentially unique to uranium mining, and a much greater focus on monitoring of groundwater is required for this form of mining than for 'conventional' open-cut or underground methods of mining.

Similar concerns to those expressed in this section on uranium mining are often expressed about other operations dealing with naturally occurring radioactive materials, for example, mineral sands or phosphate processing facilities. Again, the main concerns in terms of public and biota protection often relate to chemistry rather than radioactivity. Where applicable, workers are monitored by a radiation safety plan operated in accordance with regulatory requirements.

Comprehensive discussion of the above issues may be found in reference documents produced by the International Atomic Energy Agency and the Australian Radiation Protection and Nuclear Safety Agency. A selection of these documents is listed in the 'Further reading' section of this handbook.

## **4.6 Community involvement in monitoring implementation**

### **4.6.1 Community involvement in implementation of environmental monitoring programs**

With greater emphasis on sustainable development and increasing stakeholder involvement in decision making, it is expected that communities will have a more active role in the design (see Section 3.4) and implementation of monitoring programs.

Two examples where the public have had a significant involvement in various stages of monitoring programs are Alcoa's operation at Anglesea in Victoria, and Rio Tinto Alcan's operation at Gove in the Northern Territory.

Alcoa's Anglesea project consists of a brown coal mine with an associated power station. An environmental improvement plan was developed in 2008 with input from the local Community Consultation Network (Alcoa 2008). In this, targets and actions were set, and linked to a monitoring program that confirms whether they have been met. The views of the community were taken into account when determining the location of continuous air monitoring points, and an ambient air quality monitor was installed at Anglesea Primary School in response to a community request. Continuous monitoring of ground level sulphur dioxide concentrations and the use of telemetry that transmits data back to the power station control room generates real time monitoring data that can be provided to members of the community any time on request. The data are summarised in the company's monthly environmental report newsletter, which also includes results of water monitoring and progress in mine rehabilitation (Alcoa 2009). The program is a good example of leading practice monitoring that is transparent and meets information requirements identified by members of the community.

At Rio Tinto Alcan's operation in Gove, Indigenous Traditional Owners have been involved in ethnobotanical surveys of both rehabilitated and unmined areas, to help identify important cultural elements within the ecosystem and to help the company to incorporate key elements of cultural significance into mine rehabilitation (Stokes et al. 2008). In addition, Traditional Owners have been involved in the survey of a rare and threatened species, using their local knowledge of species distribution.

Web-based consultation is an increasingly popular means by which community members can have input to various stages of a project. It is well suited to engaging young people and those unable to attend meetings.

### **4.6.2 Community involvement in implementation of socioeconomic monitoring programs**

As noted in Section 3.4, socioeconomic monitoring in the mining industry should ideally involve mechanisms for community input at each stage of the monitoring framework's development and execution, potentially including data collection and validation of outcomes.

## CASE STUDY: Leading practice community-directed monitoring and research

For many years, the catchment of the Dee River has been impacted by acid and metalliferous drainage (AMD) from the historic Mount Morgan mine in central Queensland. In 1999, the community Wowan Dululu Landcare Group identified the need to undertake an assessment of the Dee River, a tributary of the Fitzroy River.

Input from Landcare group's Dee River Subcommittee provided the basis for planning two studies aimed at improving knowledge and communication regarding acid flow impacts on downstream water and land users. The resulting research was undertaken as two master's degree projects, one with a biological focus and the other with a chemical focus. The work was jointly funded by Queensland Mines and Energy (QME, now a part of the Department of Employment, Economic Development and Innovation) and the Landcare group through the Natural Heritage Trust.



Macroinvertebrate sampling in Dee River. Source: Ros Howse.

The biological project improved the understanding of the biological impacts of AMD and the response of the biota to acid flows in the Dee River, downstream of the mine (Howse 2004). The macroinvertebrate community analysis was the most extensive conducted to date. The analysis confirmed a dramatic reduction in biodiversity downstream of the mine's chronic AMD impacts (sites 2, 3 and 3b) when compared to Site 1 upstream and Site 852 kilometres downstream (Figure 1), which had been observed in prior studies.

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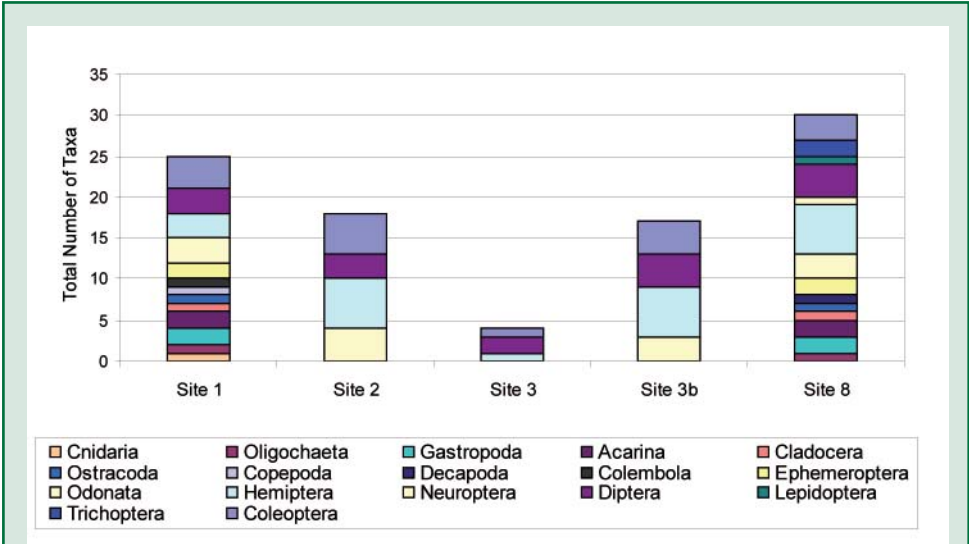
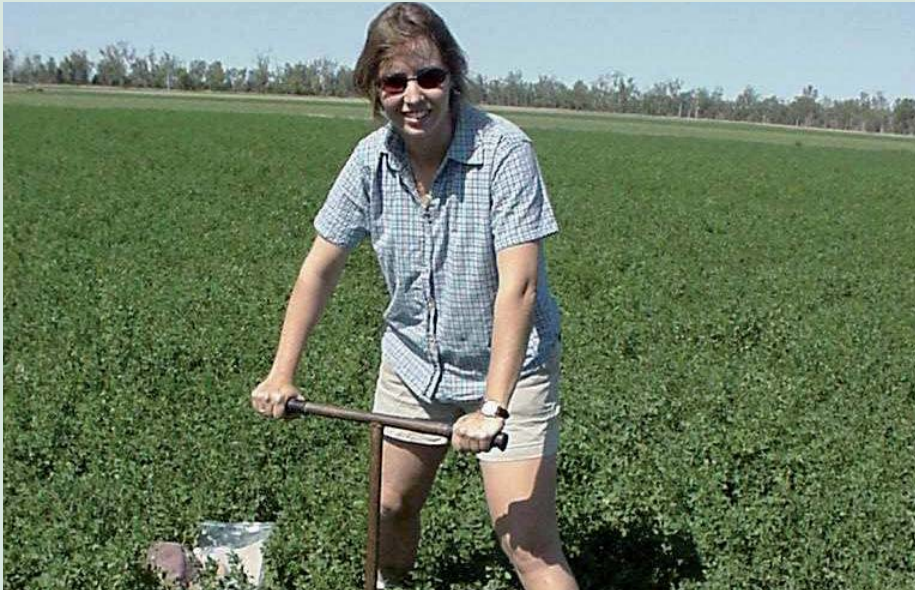


Figure 1: Total number of aquatic macroinvertebrate taxa from samples collected at five sites along the Dee River in October 1999 (Source Ros Howse, 2004). Site 1 is upstream, sites 2, 3 and 3b are the most affected by AMD impacts, and Site 8 is 52 kilometres downstream.

The metal content of fish and mussels was also determined for the first time, in response to acid flows in the river following rain events (Howse 2007). In some locations, the abundances of some of the few remaining taxa, particularly *Chironomidae* midge larvae, increased dramatically, most likely due to reduced predation and competition for those able to tolerate the poor water quality.



Floodplain soil sampling in crop land. Source: Ros Howse.

(continued)



The chemical project investigated the chemistry of the Dee River system by looking at the concentrations of selected trace elements from the mine in surface water, groundwater, sediments, soil and agricultural produce (Taylor 2004). It also assessed the potential availability of these contaminants further downstream, where the river is used for agricultural purposes, by sediment speciation analysis of one or more trace elements. Additionally, a conceptual model of the fate of the metals from the mine was produced.

During the projects, the ongoing involvement of affected and motivated members of the community significantly contributed to defining the impacts of this legacy mine site on river water quality, aquatic ecosystems and floodplain soils used for agriculture. Together, the two projects resulted in improved monitoring of the river by the Queensland Government. In conjunction with the work of the Landcare group, the findings contributed to improved consultation with downstream landholders on water quality issues and water use.

The projects also supported the overall objectives of the rehabilitation plan of the Mount Morgan mine site, which documented the current state of knowledge of the site and provided a range of future management options to reduce the AMD contaminant load to the Dee River.

The Landcare group and QME went on to jointly apply for funding of a water treatment plant through the National Action Plan for Salinity and Water Quality, with the assistance of the Fitzroy Basin Association. The project was a finalist for the Thiess National Riverprize in 2006, providing national recognition for all those involved.

Clearly the capacity of a community to actively participate in data collection depends on the form and context of the data in question. Nevertheless, a well-designed socioeconomic monitoring framework that incorporates a mix of data types and sources should seek to include some degree of active community participation at each stage of the monitoring program. Examples of community groups that may facilitate this participation include community liaison groups, schools and local associations such as Landcare groups or progress associations. It is also essential to consult local Indigenous people, including Traditional Owners, on a wide range of socioeconomic issues as well as cultural and heritage issues, as many of these issues are interrelated.

Any socioeconomic monitoring programs that fail to include a cross-section of community interests may ultimately prove to be deficient as an organisational or community reference point. Stakeholder identification tools exist to guide companies in the process of identifying primary or secondary stakeholders, including the *Community development toolkit* published by the Energy Sector Management Assistance Program, World Bank and International Council on Mining and Metals (ESMAP et al. 2005).

### 4.6.3 Handling disputes and addressing community grievances

Disputes between mines and communities, or particular groups within a community, are not uncommon. If handled well, engagement over difficult issues can help strengthen relationships and demonstrate an operation's willingness to address issues of concern (even when they cannot be fully resolved). Early engagement, community participation, impact assessment, risk analysis, commitments to human rights and community development are pre-emptive leading practice strategies that aim to avoid conflict arising in the first place.

Nevertheless, issues will inevitably arise and operations should prepare for them by establishing effective grievance and dispute resolution mechanisms as early in the mine life cycle as possible, including during the exploration phase. Monitoring mechanisms should include processes to communicate, receive, log, assess, respond to and report on complaints. Trends in incidents and complaints should be analysed and used to achieve better outcomes and demonstrate improvement in performance.

Early and inclusive engagement will help determine the optimum design for the consultation mechanism. The needs and preferences of vulnerable, minority and marginalised groups should be considered, for example, providing means to lodge grievances for people with low levels of literacy. Complaints mechanisms, whether formal or informal, should be monitored and evaluated on a regular basis, including the degree of satisfaction with the outcome as well as with the process.

A recent study on mining and community grievances lists those elements of grievance mechanism recording and management that have worked, and those that have not worked (see Appendix 3, from Kemp & Bond 2009).

## 4.7 Data management

Considering the cost and effort that goes into collecting them, monitoring data are commonly the most expensive asset of a mining project monitoring section. It is, therefore, astonishing to see how little attention is often given to optimising data storage and management systems, and the uses to which the data could be put. To realise maximum value from the investment in data collection, database management systems must be in place to ensure not only that the data are accurate and readily accessible, but also that adequate security exists to prevent tampering or unauthorised access, and that clarity and transparency are achieved in the reporting process.

Adequate data management is the first step in data quality control. As the *Australian guidelines for water quality monitoring and reporting* note, 'Once the 'certified' data leave the laboratory, there is ample opportunity for 'contamination' of results to occur' (ANZECC & ARMCANZ 2000b). Data insertions, deletions, repetitions, the mixing of scales and the mis-assignment of sites or dates can readily occur, and such data errors can be very difficult to detect without detailed checking of the data by personnel who are familiar with the monitoring program. Rigorous data entry quality assurance and quality control procedures, using a database with appropriate authorisations for access and tracking of edits, can eliminate or minimise such errors, and are well worth the cost and effort required to implement them.



Since most data storage systems will be primarily electronic, it is critical that they are adequately backed up (both on site and off site). Ideally, hard copies of the data are also maintained. As with any aspect of quality management, good housekeeping is the essential element. The adequacy and quality of the backups should be regularly checked.

For operations with long lives it is important to use data storage software that is standard and/or readily facilitates data transfer to another system. Software systems evolve, and there is no guarantee that some software used today will continue to be supported or that future hardware and operating systems will be able to run it. For larger datasets, relational databases are generally better future proofed because the data structures can be maintained in future software implementations, and robust data transfer systems are generally well developed for them. For smaller datasets

## **CASE STUDY: Indigenous community involvement in monitoring**

Rio Tinto Alcan's Weipa bauxite operation is located on the west coast of Cape York Peninsula in far north Queensland. The operation implements a community engagement program that includes ongoing consultation with Traditional Owners to identify potential impacts and opportunities prior to expanding the mine into new areas. The information gathered through these activities is included in the development of a management plan for communities, heritage and environment.

As part of its next expansion, Rio Tinto Alcan plans to move its mining activity into the area north of the Mission River, east of Andoom Creek. This area encompasses the traditional lands of the Thanakwithi people and is referred to as Luenh and Bweening. This is the first time mining will impact on this area, and there will be significant changes made to the landscape. Therefore, Rio Tinto Alcan personnel have collaborated with Traditional Owners to develop the Luenh and Bweening Communities, Heritage and Environment Management Plan.

Extensive community-led consultations were carried out in order to gain a full understanding of the cultural heritage and social values of the area and to identify the Traditional Owners' priorities and concerns. A community-led approach ensured the management plan was written in partnership and reflects the views of the Traditional Owners. This approach facilitates a culturally appropriate method of communication and consultation that has been extremely helpful when talking about sensitive topics, for example, the construction of a new haul road over a waterway.

The Communities, Heritage and Environment Management Plan seeks commitments from various parties for the ongoing management of the area. Annual audits will be used to monitor and evaluate the effectiveness of the management of the area. To be successful, these audits will include accurate assessments of the mine, access tracks, the haul road creek crossing, sacred story places, scar tree monuments, heritage artefacts and important places.

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Annual audits involve Traditional Owners and Rio Tinto Alcan representatives visiting each location together and monitoring and evaluating the impacts of mining. Annual trips to the mine provide visual demonstration of the changes in mining activities in the area. Audits of sacred places evaluate changes to the environment and rate Traditional Owners' satisfaction with the condition of these places. These assessments allow for early detection of impacts and effective remedies. They also help prevent irreversible damage and unnecessary distress to the Traditional Owners.

and projects of short duration, standard spreadsheet formats can provide adequate future proofing, but they may not be the best option if they do not facilitate data quality checking.

A number of relational database packages tailored for monitoring data are available. The leading packages usually include the ability to automate some aspects of data quality checking and provide for data quality scores to be associated with the stored measurements. Such facilities are highly recommended for leading practice data management. In selecting a package, it is essential that its suitability and coverage of data types are matched to the requirements of the monitoring program. It is ill-advised to match monitoring information content to suit the capabilities of the software, since this may mean that a number of important components of the monitoring program cannot be effectively incorporated into the data structure.

Flexibility and adaptability in data management systems should be regarded as necessities in the selection process for a monitoring data management package. The sites, parameters and precision of monitoring may change over time in response to changing management needs. The data management system needs to be sufficiently flexible to accommodate these changes, and maintain the right balance between standardisation to facilitate data quality management and adaptation to facilitate optimisation of the monitoring program. Usually this will entail a multi-level security system, so that only an authorised and technically competent system manager is able to make the changes necessary to adapt the database structure to changing data management needs.

Most modern monitoring programs include the collection of different types of data. These may include datasets of different sizes, such as continuous or semi-continuous time series measurement, and discrete samples of a limited number of parameters. Alternatively, they may include datasets of different levels of complexity, such as biological measurements of several parameters for different body parts of individuals of several species from different taxonomic groupings, collected using several different sampling methods at a number of sites on a number of occasions, as well as spot water quality measurements once a month with few parameters per sample.

Leading practice use of the different datasets includes comparison and synthesis of results as multiple lines of evidence of response to mining operations. Where possible, this should be facilitated by use of a single data management system, but it might not be possible to effectively include all types of monitoring data in a single system. Standardisation of some data elements across datasets, such as use of

common site code descriptors, can be a very useful tool for facilitating analysis of data stored in different databases.

The data systems must be accessible to those that need to use them, and sufficiently clear that new users are able to use them quickly and access the monitoring data as required. There will usually be some learning required in order for a new user to understand the system, but this requirement should be minimised. Clarity in data management systems should extend to data sources, their quality and their relevance. Remember that the person in charge of the data now may not be the person responsible in years to come. Leading practice data management systems facilitate transference of the monitoring knowledge base.

## **CASE STUDY: Community engagement which extends beyond compliance**

Newmont Waihi Gold (NWG) in New Zealand recognises that the provision of factual and timely information is essential in building relationships with the community and stakeholders; for this reason, NWG has always maintained an 'open door' policy. Community partnership has always been integral to the operation of NWG, throughout project planning, construction, operations and rehabilitation.

NWG's Martha and Favona gold mines are located at Waihi, south-east of Auckland. The Martha open pit mine is located in the middle of the Waihi township. Waihi has a population of approximately 4,700. Ore and waste rock are conveyed through the town to a rural setting where the ore processing plant, tailings storage facilities and water treatment plant are located. The Favona underground mine is located in the vicinity of the ore processing plant.

Waihi has a close affinity with mining activities, as they have been undertaken in and around the town for more than 100 years. The modern Martha mine was permitted in 1987, and an extension to the mine, the Martha Mine Extended Project (MMEP), was permitted in 1998-99. NWG and its predecessor companies have always acknowledged the importance of working with the Waihi community. This commenced with the establishment of a community liaison forum which held regular meetings for several years leading up to the 1987 mining licence hearing. A similar body met regularly in the years leading to the MMEP.

The environmental monitoring program has been influenced by the close proximity of residents as well as the sensitive nature of the receiving environment. Excess water is treated and discharged to the Ohinemuri River, which contains trout as well as indigenous species of fish. The environmental aspects of the Waihi operation are controlled by the conditions of a mining licence as well as resource consents.

The Martha mine, MMEP and Favona mine were all permitted after a public hearing process. In all three cases the monitoring programs were developed by NWG using advice from technical experts. The proposed monitoring programs were reviewed by regulators to ensure that what was proposed would be

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effective in monitoring adverse effects. Community submissions on proposed monitoring programs have resulted in changes to consent conditions.



**Martha mine open pit, situated in the middle of Waihi township.**  
Source: Newmont Asia Pacific.

Monitoring activities are undertaken by a team of environmental technicians employed by NWG. The monitoring system covers monitoring for dust, noise, vibration, dewatering and settlement, water quality and aquatic biology. An example of this is the use of Blasthub, an email system that records and notifies mine management, environmental technicians and the regulators of a blast measurement within 20 minutes of the initial blast. In the event of a complaint relating to vibration from blasting, a roving monitor is used to undertake additional blast monitoring.

As part of the conditions of consent NWG is required to employ a company liaison officer to act as a direct point of contact for the community and the councils. NWG has a 24-hour free-call number which goes through to the company liaison officer's mobile phone. When a call is received it is logged and appropriate action is taken. Complaints and concerns are generally followed by a site inspection and, where appropriate, additional monitoring and/or mitigation. Relevant monitoring results are communicated back to residents.

In addition, the company supplies the regulators with regular reports that include monitoring results as well as reports that summarise any complaints and concerns received, and the actions taken. In some cases, the consent conditions require the company to prepare management and/or monitoring plans and annual reports. In most cases the management/monitoring plans require regular review and approval by the regulators. This gives all parties flexibility while ensuring that the monitoring systems remain appropriate via the approval process.

*(continued)*

In order to get information out to the broader community, the mine publishes a fortnightly newsletter in the local newspaper. The contents address the results of air quality, water quality, vibration, bird, aquatic and other monitoring undertaken at the site, and provide information on upcoming mine-sponsored community events. Daily blast times are also notified to members of the public who wish to be included on a phone list. The Martha mine website ([www.marthamine.co.nz/](http://www.marthamine.co.nz/)) also publishes this information.

As part of its commitment, NWG supports the Waihi Community Vision, a community body established to assist the company to prepare appropriate projects in readiness for closure. These projects are environmentally, socially, economically and culturally based. The Waihi Community Vision also acts as a 'community audit' of how the company is communicating its operations to the public, and as a way of testing the proposals and future plans of the company.

The Martha mine operates 'within' the township of Waihi. NWG has understood the significance of this concept and continually seeks to operate at a higher level than that set out by the requirements in the mining licence and resource consent conditions, in order to sustainably manage its operations.

Maintaining corporate memory of monitoring and auditing results can also be a big issue for a mining project. In an industry where rapid staff turnover is common, procedures must be in place to ensure that monitoring techniques, locations, data and reports are securely recorded in a manner that will enable new staff to continue monitoring programs without any loss of information or quality control.

A robust spatial data base is also an essential requirement for keeping a record of the location of all monitoring sites. A common problem relating to spatial data management is that of different mapping datums being used. Mine grids are often superimposed over local map grids, making conversion of data necessary. This is a straightforward task if the process is known or well documented. However, it can lead to errors if there is a high turnover of staff, or if data points are plotted onto base imagery during geographic information systems (GIS) spatial data management without rigorous review and checking.

The use of spatial data acquired by portable global positioning systems (GPS) units is becoming increasingly common, and the selection of a common datum is essential for the accurate positioning of field points. Alternatively, for higher accuracy, electronic distance measurement survey methods are used.

GIS software can also be used to point and click on specific monitoring details (contained in separate spreadsheets but linked to the GIS). Particularly large or complex sites may require the use of data visualisation tools which provide a link between the spatial data and a range of conventional data sources in spreadsheets and databases. Leading practice requires good integration of monitoring data with GIS, web-based interface and/or site operational data and information management systems.

## 4.8 Data analysis and interpretation

Although consistently meeting regulatory requirements in relation to monitoring is an important component of leading practice, in itself it is not leading practice. Leading practice requires that analysis and interpretation of monitoring data commences early and remains an ongoing process, so that companies can identify and address problems as soon as possible, preferably before they become significant. For example, staff should be encouraged to note any unexpected readings as soon as possible while conducting monitoring—not days or weeks later when results are analysed in more detail.

As well as following routine monitoring procedures, staff should observe and report aspects that could help with subsequent data analysis and interpretation, such as the presence of:

- sick or dead fish, when conducting water monitoring for heavy metals, dissolved oxygen and so on
- algal blooms, when collecting water samples for nutrient analysis
- tree yellowing or other possible signs of nutrient deficiency or dieback, when monitoring rehabilitation plantings or unmined native woodlands.

Unusual or extreme events such as floods could be filmed or photographed to record visible water quality indicators such as turbidity. Other anomalies in monitoring data compared with previously measured values may indicate problems with the maintenance or calibration of monitoring equipment, which need to be identified and corrected as soon as possible.

Leading practice monitoring and data analysis require a conscious effort to go beyond routine regulatory requirements in terms of:

- collecting data, for example, including observational data and taking extra samples if required
- ensuring that the samples are representative of what is really happening, by adapting the monitoring schedule to the nature of the event that is occurring—this is not always the case when simply following routine regulatory procedures.

Early analysis of monitoring data can also prove useful in refining monitoring procedures. In some instances, it is leading practice to conduct a pilot study and data analysis to iron out problems with sampling and analysis. This can include ensuring the sampling design is compliant with the implicit assumptions in the preferred statistical analysis design, understanding variation, using power analysis to optimise the amount of sample replication and analysis designs, and other aspects of data analysis.

Data should be analysed as soon as possible to ensure rapid feedback is available to operators and stakeholders, and that any problems which are identified can be addressed as soon as possible. Standard practice requires that the data be analysed and compared against agreed objectives and targets or standards. Leading practice goes beyond this and seeks to provide early warning of possible problems by analysing trends (either visually or using statistical analyses). Companies may choose to set more stringent internal 'trigger' levels to initiate further investigation.



The use of agreed statistical procedures will often be required to analyse and correctly interpret the data obtained using carefully designed monitoring programs. This can result in a more accurate determination of whether objectives and targets have been met, and help resolve situations where legal issues may be involved. However, even when statistical procedures have been agreed to, it is still essential that exploratory data visualisation (such as graphs, tables and GIS plots) is undertaken to examine patterns and trends and, if appropriate, that investigative statistical analyses are conducted to ensure unforeseen changes are detected early and the applicability of the agreed statistical analyses is maintained.

In some situations, small sample sizes or other limitations may preclude the use of some conventional statistical analyses (for example, analysis of variance). This applies especially to those cases where there is a consistent trend through time. In these instances, analysis of trends and other procedures may be needed to detect changes. The use of Bayesian statistics has recently revolutionised analysis of small sample sizes, and there are several other robust classical statistical tools that may be suitable. Simple field trials and detailed observations can also help greatly in understanding the causes of impacts and the processes of recovery.

Whatever the case, it must be remembered that statistical methods are simply hypothesis-testing or hypothesis-generating tools, and are no substitute for the examination of quality data from an informed environmental science viewpoint. Routine, mechanical statistical testing of compliance may be standard practice, but leading practice requires data interpretation that takes into account understanding of the processes in the receiving environment and the mechanisms of action of the stressors of concern. Therefore, most leading practice comprehensive monitoring programs and practices will include both sound experimental design and statistical analyses, together with detailed observations.

As well as being used in the context of immediate compliance, the analysis of the results from monitoring programs should also be used to investigate any trends in incidents. An increasing frequency of failure can point to a developing adverse condition. Incidents can range from near misses to spills with significant environmental or safety impacts. Recording the details, impacts and frequency of events and analysing this information in relation to operating procedures can be useful for both reporting and improving performance. It is standard practice to record these details in sites with AS/NZS ISO 14001:2004 compliant environmental management systems. Leading practice takes this a step further by analysing the data and acting on the results of the analyses.

As well as the obvious aspects of the interpretation of analyses, such as determining whether objectives, targets and standards have been met, leading practice includes a strong focus on continuous improvement. Leading practice companies clearly understand that monitoring provides the information needed to identify problems and to assess the effectiveness of remedial measures. Procedures are set in place to ensure that the findings of monitoring programs are reviewed by company environmental and operations staff. Results are inspected in conjunction with records of events (for example, a change in operating procedure) and actions taken (for



example, to explain an unexpected rehabilitation outcome) in order to determine causes and explain results. In some instances further investigation, monitoring or research, including root cause analysis, may be required. Modifications to the monitoring program may also be needed.

Objective analysis and interpretation of data, with a strong focus on continuous improvement, can result in changes to operating procedures and consequently better environmental, economic and/or social outcomes.

## 4.9 Completion criteria

'Completion criteria' (also known as 'success criteria') are critical elements of the mine closure process. The mining company requires completion criteria in order to:

- demonstrate that rehabilitation and other objectives have been met
- close the mine
- relinquish the mining lease.

Leading practice completion criteria go beyond physical mine site rehabilitation and closure to include social and economic criteria, in order to establish sustainable outcomes in communities which may have been negatively impacted by mine operations and/or closure. Governments need reliable measures of rehabilitation success to ensure the sites are stable and sustainable, and the community is not inheriting an ongoing liability. Finally, the public wants to know that the rehabilitation will be successful; that the site is non-polluting, not impacting beyond mine boundaries, and safe for humans and fauna; and that sustainable land use will result. Examples of leading practice signoff can be found in the *Mine closure and completion handbook* (DITR 2006a).

While completion criteria are a key requirement for demonstrating rehabilitation success, meeting regulator and other stakeholder expectations for mine closure also requires criteria relating to other parameters. These might include criteria relating to water quality (for a range of water bodies and downstream creeks/rivers), contaminated land, visual indicators linked to aesthetics or belief systems (for example, landforms not visually impacting on significant landmarks), agricultural productivity of farmland, and geotechnical stability. The need for each criterion would be defined during risk assessments and life-of-mine planning.

Procedures for developing completion criteria are described in a number of documents including the *Mine closure and completion*, *Mine rehabilitation and Biodiversity management* handbooks in this series (DITR 2006a, 2006b and 2007a). Other key references describing important aspects of the process include the International Council on Mining and Metals mine closure toolkit *Planning for integrated mine closure* (ICMM 2008) and the Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia *Strategic framework for mine closure* (ANZMEC & MCA 2000). In simplest terms, a clear closure objective is needed, accompanied by auditable measurement criteria which can be used to establish that the objective has been achieved. The criteria, together with any associated targets and standards, must be clear and unambiguous, and measurable by methods that all parties can agree on with confidence.

Monitoring, auditing and research can play a key role in the development of completion criteria by demonstrating what impacts have occurred due to mining activities, and the extent to which rehabilitation can replace the values impacted, as outlined in the agreed objectives. The results can be compared with stakeholder expectations, and the criteria, together with any associated targets or milestones, can be modified according to new information, subject to the agreement of stakeholders. A process for developing ecological criteria is described in Nichols (2004, 2005 and 2006) where it is illustrated by example in several case studies, and shown using a flowchart in Figure 1 of Nichols (2006).

For most projects, monitoring and auditing for performance evaluation will also have an important role in demonstrating that agreed completion criteria have been fulfilled and rehabilitation objectives have been met. Completion criteria can be derived from a number of sources, such as the conditions of a mining lease or an enabling agreement, agreements with individual landowners, or regulatory requirements. The biophysical and social contexts of the mine also need to be taken into account. Often an operation will commence with some broadly agreed closure objectives and associated completion criteria. As the mine evolves, these may be adjusted to reflect changing community expectations, where these are able to be accommodated. The criteria may progressively become more refined and specific as the actual mine closure approaches. Changes made to the agreed completion criteria, for whatever reason, may require altered monitoring procedures and auditing criteria.

Leading practice requires that, where practicable, mines implement progressive rehabilitation on an ongoing basis during mining operations. This can be linked to progressive signoff through evaluation of rehabilitation performance, and thereby increase stakeholders' confidence in relation to rehabilitation outcomes and the mine closure process. Where progressive rehabilitation is carried out, definitions of rehabilitation success may need to be modified to cater for specific aspects of the rehabilitation process. For example, if progressively rehabilitated areas have poor connectivity with undisturbed areas, opportunities for fauna return and natural seed recolonisation may be more limited.

Completion criteria will generally be developed for each 'domain': that is, for each different area of the mine, including the open pit, waste rock dump, TSF, infrastructure and so on. These criteria will include consideration of social, cultural, economic and environmental values, all of which will need to be measured or assessed in some way to determine whether the target or milestone has been met.

For example, completion criteria for the closure and rehabilitation of open pits, waste rock dumps and TSFs will commonly include consideration of the following elements:

- The final waste landforms are physically and chemically stable; they are safe for people and animals; blend with the surrounding landscape and are aesthetically and functionally acceptable.
- Open pits, surface waste rock dumps and TSFs maintain geotechnical stability.
- Seepage to the receiving surface and groundwaters can be assimilated by the receiving environment and will not cause unacceptable harm.

- Open pits remain regional 'sinks'; if backfilled, the need to remain a sink will depend on the geochemical characteristics of the backfill material.
- All drainage works remain functional and stable.
- Erosion loss rates do not cause unacceptable environmental harm or geotechnical instability, or threaten sustainability of vegetation communities.
- Downstream water quality will not be negatively impacted by mine runoff and seepage.
- Stream flows are not permanently reduced by the presence of the post-mining landscape (for example, catchment diversions).
- Final void water quality matches the post-mining land use requirements and community expectations.
- Dust generation does not cause unacceptable amenity or health impacts, or unacceptable harm to the environment.
- Soil nutrient banks are establishing and soil chemical and physical properties are suitable for the intended post-mining vegetation.
- Appropriate vegetation is established and sustainable, and satisfies the agreed post-mining land use, which may be an agricultural (cropping, grazing or both) system, or a native ecosystem.
- Fauna are recolonising any rehabilitated native ecosystems in adequate numbers and diversity.
- It is important to demonstrate that completion criteria can (and will) be met over an extended period of time.

Socioeconomic completion criteria are usually whole-operation matters, and often extend beyond mine boundaries to encompass other infrastructure (such as roads, rail and ports) and support systems and associated communities connected to the operation. The impacts of a mine on a community, and on local and regional businesses, can be very broad. They can relate to where the workers, contractors and suppliers are located and how that influences the local and regional economy.

Community baseline studies enable relevant information on the population and economy to be gathered and appropriate completion criteria to be developed. Criteria are influenced by the population and skills mix of the local community, and business activity either at the mine site (for example, adaptive reuse of buildings, or interpretation of mining heritage through tours) or in neighbouring communities. An important part of mine closure is ongoing monitoring of the success of social and community development programs, for example, through periodic household surveys seeking information on improved health, education and economic status of the communities.

It is important to monitor or audit the financial aspects relating to mine closure. Rehabilitation is often an annual operating expense included in the annual budgets of the mine. Environmental audits of the mine should ensure that adequate funding is available for the planned rehabilitation program for that year, and that adequate funding was provided for and spent in the previous period. An important

consideration is whether the approved funds were actually used for rehabilitation or diverted to another purpose. Rehabilitation monitoring results form an important part of the audit evidence; if the monitoring procedures are not adequate, this should be identified in the audit.

The issue of funding for mine closure can pose challenges. While annual rehabilitation budgets are relatively easy to establish and monitor, the cost of closure to meet the completion criteria is more difficult to assess. However, these costs should still be modelled, and should be reviewed at key milestones in an operation. Ideally, this should occur annually; however, three-year to five-year time frames may be adequate during expansion phases. Leading practice monitoring and auditing criteria should ensure that internal funding is established to achieve both completion criteria and regulatory financial assurance requirements, verifying that sufficient funds are provided throughout the mine's life to allow for both planned closure costs and contingency costs for unexpected developments. Costing and provisioning for mine closure are discussed in more detail in the *Mine closure and completion* handbook in this series (DITR 2006a).

## 4.10 Safety of monitoring

Leading practice environmental monitoring includes leading practice management of the safety of the personnel involved. While mine operations are required by law to maintain high standards of safety, monitoring programs often involve activities that are otherwise atypical of mining project practices and may not be covered by the standard safety practices for the project. This can be especially true of short-term or one-off monitoring projects or tasks, such as spill response or special investigations.

Environmental and social monitoring may require sample collection well outside the project boundaries, such as in reference areas or areas upstream, well downstream or downwind of the operations. Standard mine site safety procedures or personal protective equipment (PPE) requirements may be inappropriate and even potentially hazardous in some circumstances. For example, water quality monitoring may involve accessing sampling sites by boat: the wearing of steel-capped boots, a standard mine site requirement, could substantially increase the risk of drowning in the event of a boating accident.

As many mine sites are in remote areas, monitoring at locations remote from the mine site can further increase the risks to personnel. The safe communication requirements and transport backup systems for monitoring staff can differ greatly from the requirements for other mining project staff. Monitoring staff may be exposed to hazards that are rare or simply do not occur in the main mining areas, such as aggressive animals or fast currents. For example, crocodile attack is a very real risk for environmental water sampling in many parts of northern Australia; crocodiles have even been recorded in open mine pits, water storages and tailings dams. Getting lost can be a real risk at some sites, especially for less experienced staff; this risk can be addressed by comprehensive safety training and induction and the use of up-to-date maps, GPS, good communication systems and reporting procedures, and emergency beacons or radio-tracking devices.

Furthermore, weather conditions during some of the critical times for collecting monitoring data, for example, when plants are shut down during storms or wet season flow events or periods of extreme temperature, pose additional risks to monitoring staff. The data collected during these periods may be particularly valuable for environmental management, but must only be collected in a safe manner.

These special safety requirements for monitoring need to be carefully considered for each monitoring program element, and ways to minimise and/or eliminate the risks need to be developed. Typically, this will require the development of standard operating procedures that are specifically developed for the monitoring tasks, the allocation and approval of specialised PPE for some tasks, and detailed task safety assessments for each new monitoring task. In all cases it is important to address the real safety issues for the monitoring task, and not rely on standard site practices that may not be appropriate.

## **4.11 Monitoring technologies**

### **4.11.1 Real time monitoring**

Many mining operations use technology and communication platforms to operate their fleet of earth-moving equipment and their process plants. The use of telemetry networks for monitoring is just an extension of this management technique. It allows the monitoring staff to acquire information and act proactively, rather than reactively. The benefit is that the environment can be managed and operated in the same manner as the 'process plant' on the mine site. Telemetry networks can have a cost benefit by reducing the effects of incidents, and the associated clean up, by early intervention. They can also have safety benefits by reducing the frequency of staff visits to remote monitoring locations.

Leading practice telemetry projects use appropriate technology and communications platforms to achieve their set objectives, not just the latest technology. When developing a project of this nature, it is important to discuss requirements with a specialist. Apart from the immediate need to get data from A to B, the design must consider the telemetry bandwidth, network support, communications protocol, power consumption, data delivery, data storage and data display.

Leading practice requires the data to be delivered and accessible to the end user in a simple format. This does not mean that it has to have graphical displays; rather, it should deliver the data in a format to meet the objective. For example, some integrated GPRS (general packet radio service) data loggers can send an alarm out using voice messaging and SMS (short message service) and an email of the dataset. This links field officers to their field instruments through smart mobile telephones. On the other hand, radio telemetry networks are normally site-based with limited capabilities to transmit off site, and may be affected by topography or atmospheric conditions such as storms.

## **CASE STUDY: Designing a post-resettlement social monitoring program**

The Gold Ridge project is located on the island of Guadalcanal, Solomon Islands, in a highland area southeast of Honiara. In 1997, a mining lease covering 30 square kilometres was granted to Gold Ridge Mining Ltd (GRML), a Solomon Islands company which was then a subsidiary of Ross Mining, an Australian company. Ross Mining developed the mine and operated it from August 1998 to June 2000, producing approximately 210,000 ounces of gold before civil unrest forced the project to close.

In 2004, after order had been restored in Solomon Islands, Australian Solomons Gold Limited won a tender process to reopen the mine and signed an agreement to acquire GRML, including the mining lease and surrounding special prospecting licence. ASG took possession on 30 May 2005.

The customary landowners of the site are members of 16 closely related tribes who have been engaged in gold panning in the area since the 1950s. Under Solomon Islands law, customary landowners have considerable rights in relation to mining projects, enabling the Gold Ridge Community and Landowners Association to negotiate an agreement providing for royalties, financial compensation, resettlement assistance, and income restoration and community development programs. Agreements were also negotiated with the downstream communities potentially affected by the mine.

Before mining operations commenced in 1998, the customary landowners and their extended families, approximately 1,200 people in total, were resettled to other villages. After the mine closed in 2000, approximately 60 per cent of the relocated people returned to the mining lease area and resumed gold-panning activity. They were joined by a number of immigrant artisanal miners without recognisable claim to the land.

To recommence mining, GRML had to resettle a total of 1,256 potentially displaced persons, comprising the customary landowners along with the immigrant artisanal miners residing within the mining lease area. The landowners were fully aware and supportive of the need to vacate the site to allow mining to commence so that they could receive royalties and other benefits associated with the mine. The immigrant artisanal miners were on the site with the acquiescence of the landowners and also accepted the requirement to move.

The resettlement strategy is detailed in the resettlement action plan (RAP) (Australian Solomons Gold Limited 2009). The design of the resettlement monitoring program is based on the International Finance Corporation (2002) resettlement handbook, and includes internal performance monitoring of the RAP and social impact monitoring for the life of the mine. Feedback from internal and external monitoring of both the RAP implementation process and social impacts will be used to inform policy and administration.

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All formal monitoring processes require reporting to both senior management and consultative groups representing the resettled community. When the physical relocation process, including major income restoration measures, is complete, a completion audit of the implementation of the RAP will be undertaken. A full evaluation of the success of the process will only be possible after a number of years of ongoing social monitoring.

The internal performance monitoring process for resettlement is carried out by the GRML Community Relations Department, with assistance from the affected communities through the Gold Ridge Women's Task Force and Gold Ridge Youth Executive, supported by ten village-based zone committees. Performance monitoring of the process will focus on the achievement of project milestones identified in the RAP. Monitoring will also record the achievements of ongoing community development and income restoration activities which will be continued throughout the period of resettlement.

The social impact monitoring will be conducted by both GRML staff and community representatives (continuously) and external independent auditors (annually). It will commence six months after resettlement has been completed, with a baseline survey. At the end of the first year and annually thereafter it will include the following elements:

- social—registered crimes/disputes; registered crimes/disputes involving vulnerable groups; registered crimes/disputes involving women; school attendance; number of community-based organisations
- economic—percentage of households owning land and/or owning house and/or growing own food; employment; average household income; average household expenditure; percentage of community employed by GRML
- health—birth rate; death rate; infant mortality; incidence of disease.

To identify the appropriate technology, the project's objectives should be considered and, as a minimum, the following questions should be addressed:

- Is the data required in 'real time' for operational purposes or 'almost real time' for post-event management and alarm purposes?
- What is the quantity of data to be relayed over the network? The selection of technology must have adequate bandwidth to both manage the immediate data and allow for future expansion.
- What infrastructure is in place that can be utilised for the telemetry network? This can be site-based radio telemetry or publicly operated networks such as mobile telephone GPRS systems or satellite telemetry.
- What communication protocols do the field instruments use and can the telemetry unit accept their input?
- What is the geographic coverage required? Consideration should be given to vegetation (signal attenuation) and topography.



The telemetry solution is not appropriate if the data is inaccessible or the data resolution is compromised by the telemetry platform. It should also be noted that field verification, calibration and maintenance are still required.

### 4.11.2 Limits of detection for chemical parameters

When choosing the levels of resolution (that is, the detection limits) for monitoring parameters, it is important to consider the reasons for collecting the measurements and the time span over which the measurements may be used. Over time, analytical methods tend to improve and the levels of resolution achieved tend to improve as detection limits decrease. Corresponding with this, target standards and guidelines also tend to reduce as community perceptions of acceptability tend to tighten over time. It is true to say that the current standard commercial laboratory analytical methods are not able to detect all the toxicants in the *Australian and New Zealand guidelines for fresh and marine water quality* at levels below the trigger values (silver is a particular issue of relevance to mining) (ANZECC & ARMCANZ 2000a). While it may be acceptable now to report the current practical quantification limit as an indicator of water quality for such parameters, this will not remain the case as analytical methods improve.

For these reasons, it is important in the earlier stages of a project to aim for the lower range of detection limits that are currently achievable, and at all stages to regularly reassess the levels of resolution that are requested of the analysis laboratory, or specified for field or site monitoring equipment purchases, to maximise the relevance of the monitoring data over time. As mentioned in Section 4.7, monitoring data are often the most valuable asset of a mine environment section, and built-in obsolescence should be avoided as much as possible.

This may mean that consideration should be given to the use of 'cutting edge' or research analytical methods rather than standard, mid-priced commercial analysis, at least for key parameters and sites. Baseline data can never be repeated, so it is worthwhile to consider paying for improved levels of resolution at the initial stage, even if later impact monitoring does not have such stringent requirements.

For some parameters, extremely low levels of resolution are possible, but may not be achievable for non-specialist personnel or laboratories. The sample preparation, collection, handling, shipment and analysis quality control requirements for measurement of, for example, dissolved metal concentrations in the nanogram per litre range (important for some elements in some circumstances) are much greater than for levels of resolution in the low microgram per litre range (more typical for aquatic ecosystem protection for most metals), which in turn are much greater than for measurement in the upper microgram per litre and milligram per litre ranges (more typical for human drinking water considerations). The fact that a laboratory instrument has specifications indicating that it can achieve a particular level of resolution does not mean that accurate measurement can be achieved in practice without specialists being involved at each stage, from container preparation, sampling and delivery to the laboratory through to laboratory analysis and reporting.

The key issue is that leading practice considers what analytical methods are appropriate for the project's data needs, both now and into the future, and selects methods that are appropriate to those needs. Leading practice never selects methods on the basis of current laboratory pricing structures.

### **4.11.3 Other technology considerations**

Many leading practice monitoring methods are being developed or have been developed to meet particular needs. These include methods such as:

- improved sensor technologies, including the development of biosensors
- specialist remote sensing methods
  - on land, such as high-resolution satellite imagery of varying wavelengths and combinations of wavelengths
  - on water, such as hydro-acoustic sampling of aquatic organism position, density and size frequency, acoustic Doppler current profiling of water and suspended sediment movements, and field water quality test kits
- improved non-destructive animal sampling, such as frog recorders, bat detectors and DNA analysis of hair tube samples
- fauna radio and satellite tracking devices to assess habitat recolonisation
- instruments for measuring vegetation water uptake.

Importantly, leading practice monitoring does not select standard default technologies or cutting-edge technologies because they may be cheaper or provide cache. Leading practice uses technologies that are appropriate to the monitoring program and its data needs immediately and into the future.

## **4.12 Long-term relevancy**

As pointed out in sections 3.1 to 3.6, planning for monitoring should always be carried out as a life-of-mine exercise, with the relevancy of data collected at each phase maximised for use in later phases. Section 4.11.2 notes that this may require, for example, that baseline data collection chemical limits of detection are well below standard commercial practice at the time, to maintain relevance at later stages of projects with a long lifespan. It is essential that there is accurate and transparent reporting of data quality and maintenance of access to datasets through the life of the project. As noted in Section 4.7, the future users of data are unlikely to be the original collectors, due to staff turnover, and the future users must be able to access the results, understand their provenance and be assured of their reliability. Leading practice addresses these life-of-project issues and ensures that data management systems and decisions on data collections maximise the continuing relevance of the data.

## **CASE STUDY: Post-closure remote monitoring to provide early warning of potential issues**

The Benambra mine is located in the remote upper catchment of the Tambo River in north-eastern Victoria. It was operated by Denehurst Ltd as an underground base metal mine from October 1992 to July 1996. During operations, 927,000 tonnes of ore was processed on site to produce copper and zinc concentrate, and nearly 700,000 tonnes of tailings from the process plant was delivered by pipeline to a nearby tailings dam.

With the help of consultants, the Victorian Department of Primary Industries (DPI) developed a rehabilitation strategy to restore the site to as near to pre-mining conditions as possible. An environmental management plan, including a detailed monitoring program, was established for the rehabilitation works and post-rehabilitation phase.

DPI is responsible for implementing the plan. Review of the plan, including the monitoring program, by the DPI and the Environment Protection Authority Victoria (EPA) is scheduled to take place annually for the first four years post-rehabilitation and thereafter at a frequency agreed by the DPI and EPA.

The key environmental risk is the potential for water quality issues associated with acid and metalliferous drainage (AMD) from the tailings.

The water monitoring program undertaken during rehabilitation involved the collection of water quality data and samples for laboratory analysis. At the completion of rehabilitation, a remote monitoring system was installed at the tailings dam to continuously monitor rainfall, water level and key water quality indicators—pH, temperature and electrical conductivity—in order to monitor the effectiveness of rehabilitation and provide early warning of potential water quality issues. Rainfall data are logged in 0.2 millimetre increments; the remaining parameters are logged on a daily basis. The data are downloaded by satellite phone weekly or as required.



Remote monitoring station at the Benambra tailings dam.  
Source: Victorian Department of Primary Industries.

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Key components of the remote monitoring system include the data-logging hardware and software, power supply (a 12 volt lead acid battery, a 60 watt solar panel and a regulator for battery charging), water quality sensors (measuring pH, temperature and electrical conductivity), water level sensor, tipping bucket rainfall gauge, satellite phone system and modem.

Results from the monitoring system were compared with field results collected manually during the first 12 months after rehabilitation, to confirm the reliability of the system. Sensor calibrations are checked quarterly or as required (the rainfall gauge is checked every six months).

Key findings from the remotely monitored data include:

- A minimum water cover of 2 metres over the tailings material has been maintained, minimising the potential for sulphide oxidation and AMD generation from the tailings.
- There is a strong inverse relationship between electrical conductivity and water level, indicating that dilution and evaporation are the main factors affecting salinity, as expected. There is no evidence in the electrical conductivity data of sulphate addition associated with AMD generation.
- A progressive decrease in pH has been observed, from around 8.5 to 7.6, over approximately six months. The alkaline pH in August 2008 was associated with treatment of the supernatant water in April 2006 during the rehabilitation process. The decline in pH is attributed to creek inflows, which are naturally slightly acidic (with pH values around 6), rather than sulphide oxidation and AMD generation from the tailings.

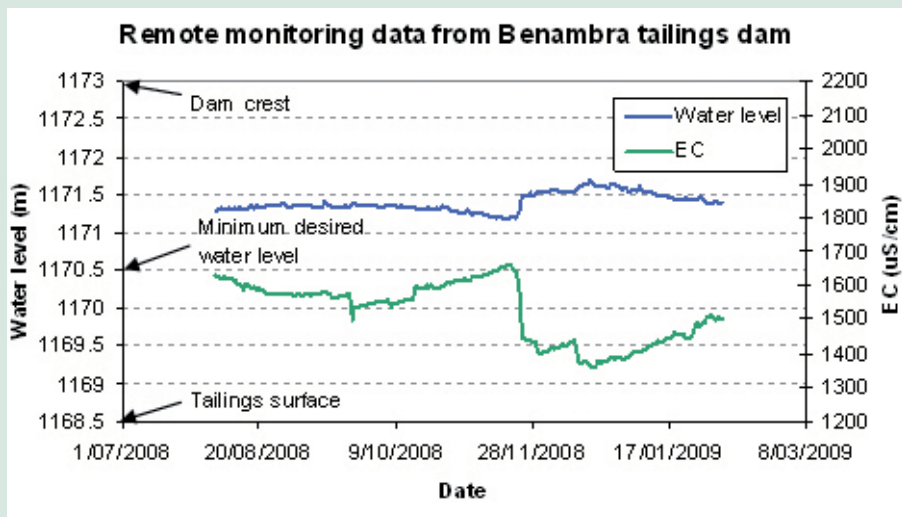


Figure 1. Long-term trends in water level and electrical conductivity (EC). Source: Victorian Department of Primary Industries.

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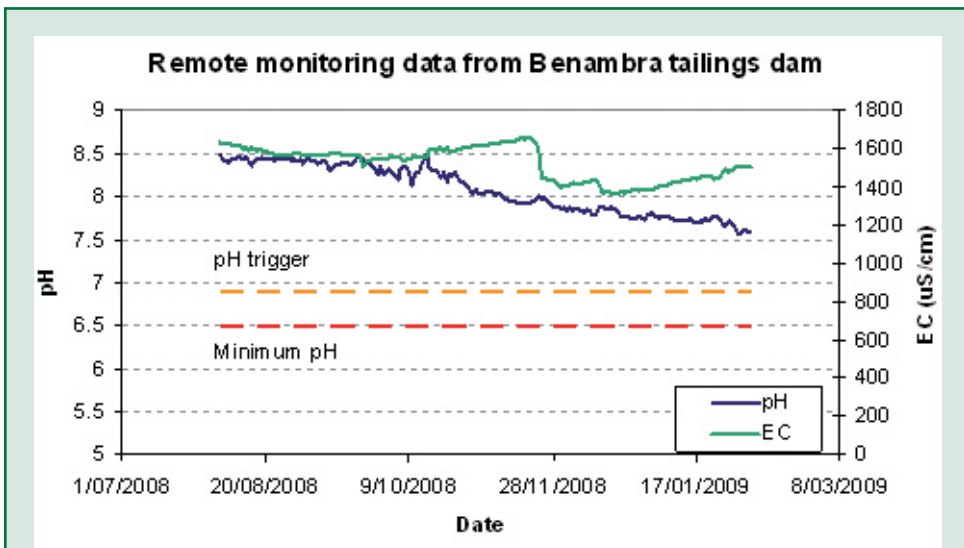


Figure 2. Long-term trends in pH and electrical conductivity (EC-microsiemens per centimetre). Source: Victorian Department of Primary Industries.

In addition, zinc and other metals/metalloids of potential concern (such as arsenic, copper, lead and manganese) would be investigated if the pH fell below a trigger value of 6.9. Management response would be triggered if the pH fell below 6.5 and/or metal concentrations exceeded maximum criteria specified in the environmental management plan. Independent tests of the water are carried out at six-monthly intervals to ensure the validity of the remote testing regime.

This remote monitoring system is an example of a cost-effective means of providing an early warning of potential long-term issues after mine closure, where the consequences of unexpected developments may otherwise be significant.

## 4.13 Public reporting and assurance

### 4.13.1 Sustainable development reporting

The public reporting of monitoring data and the findings of monitoring and research programs can cover a wide range of aspects, and target the information needs and levels of understanding of a range of different audiences. Traditionally, reporting has covered issues relating to the management of environmental impacts, such as air, water quality and noise monitoring, and the extent and type of mine rehabilitation (See Alcoa Anglesea example in Section 4.6.1). More recently, the focus on community aspects has increased, and some companies now report on a range of matters relating to health, employment, education, and the like.

## CASE STUDY: Extending technology to meet expected future requirements

The proposed Tampakan Copper-Gold Project is located north-west of General Santos City, a major growth centre on the southern Philippines Island of Mindanao. The project will be a large-scale mine with a resource estimate (as of December 2007) totalling 2.2 billion tonnes at a grade of 0.6 per cent copper and 0.2 grams per tonne gold and containing 12.8 million tonnes of copper and 15.2 million ounces of gold using a 0.3 per cent copper cut-off grade.

The area is politically complex, and the deposit sits in the headwaters of seven different catchments, most of which are heavily used by downstream stakeholders for irrigation of crops, stock watering, drinking and sanitary water supplies, and as a source of aquatic foods and other resources. All of these factors contribute to a need for rigorous, defensible baseline environmental data. In April 2007, Xstrata Copper (XCu) acquired a controlling interest in the project, with day-to-day management of the operation occurring through the Philippines-based mining company Sagittarius Mines (SMI).

Until April 2007, surface water monitoring at Tampakan had been conducted at 71 separate locations across more than ten catchments. Monitoring within these areas had been undertaken periodically from January 1995, largely by Philippines-based consultants, and consistent with the national requirements for environmental monitoring and assessment. XCu and SMI determined that there was a requirement for further feasibility studies and a more detailed environmental impact statement would be required to meet international obligations. A commitment was made to extend the pre-feasibility stage to gather the necessary additional knowledge. A substantial extension of the baseline water quality monitoring program was part of that commitment.



Filtering for dissolved metals and collecting flow measurements.  
Source: Shirley Connelly, Hydrobiology.

*(continued)*



The baseline water quality sampling and analysis program was developed on the basis of rigorous quality control, clean trace-metal sampling techniques and state-of-the-art analysis to low part per billion levels. Laboratory analysis was initially sought from commercial environmental analysis laboratories in Hong Kong and Australia, both of which had a long history of performing high-quality environmental chemistry analysis for international mining projects. The water quality sampling was conducted under the stewardship of an Australia-based environmental consultancy.

As a due diligence exercise, initial rounds of this renewed sampling and analysis program included multi-element 'scans' of 70 elements to identify any unusual elements of concern. In addition, ultra-trace metals analysis was conducted in the initial two sampling rounds, as a measure for both baseline data collection and sampling program design assessment.

As part of ongoing support and capacity building for local Philippine laboratories, analysis for selected parameters was undertaken at national environmental analysis laboratories, using sample splits sent to the international laboratories, for inter-laboratory comparison purposes. It is intended to use Philippine laboratories in preference to international laboratories where suitable quality control and assurance can be established through cooperative capacity building.

The members of the SMI Environment Department have been trained by international consultants in conducting water monitoring to high levels of quality control and assurance. This includes requiring all laboratory parameters to be within 15 per cent relative difference for triplicate samples taken during each monthly sampling round, and field blanks to be below reporting limits.



Collecting water samples.  
Source: Shirley Connelly, Hydrobiology.

*(continued)*



The result has been two years of monthly and/or quarterly (depending on sampling site location) baseline water quality monitoring data of high quality, that are anticipated to provide a sound dataset that will be of use for the multi-decadal life span of the project. This has included achieving reliable trace metal analysis results to resolution levels below 1 microgram per litre .

Such a high-quality and extensive baseline dataset was well beyond the minimum requirements for the pre-feasibility stage of a mining project in the Philippines; in terms of data quality, levels of resolution and quantity, it also exceeds the typical international requirements. However, it was seen by SMI and XCu to be of substantial benefit to the project because it would serve as a defensible baseline for many years, provided high-quality inputs into environmental management planning for the project, and provided skills training to international leading-practice standards for Philippines staff and service providers.



Stream water is used for a range of domestic purposes.  
Source: Shirley Connelly, Hydrobiology.

Leading practice reporting identifies the needs and wants of target audiences and aims to meet them through appropriate means such as community newsletters, scientific papers, community open days, websites and, in some cases, online access to relevant data. Higher level reporting now focuses strongly on sustainable development, with all leading practice companies producing annual sustainable development reports that summarise environmental, social and economic performance in relation to stated targets and commitments.

Historically, the amount and type of information that is released publicly has largely been determined by company policy. However, shareholder, institutional investor and stakeholder demand have now increased the requirements for companies to report on a range of areas that are not necessarily mandatory in terms of regulatory compliance.

The Global Reporting Initiative, as described in Section 2.1.1, is a set of guidelines for sustainability reporting. It gives the public a guide to the robustness of a sustainability report.

For some companies, the reporting process is helping to identify and manage business risks, find cost savings, address social concerns and reduce environmental impacts, among other outcomes. There is clear scope for continuing improvement in this area of sustainability reporting.

Leading practice standards exist for the provision of both non-financial company information and site-specific data. It is now generally believed that the greater the willingness to be transparent, the better the environmental management systems and overall governance within the company are likely to be. For all types of monitoring, regardless of whether they exist for environmental, financial, safety, social or even corporate governance purposes, transparency is absolutely essential, since it underpins auditing processes and the reporting of performance.

Transparency can simply be defined as the full, accurate, and timely disclosure of information. That is, monitoring data should be made available in a manner that allows relevant stakeholders timely and full access to the data. There are a variety of ways in which this can be achieved (the use of online delivery is becoming increasingly popular). Some examples include:

- A Japanese waste incinerator built an external 3 metre neon sign connected to the incinerator to prove to the local community that the temperature was always above the required 1,200 degrees Celsius—an innovative method of transparent monitoring.
- The National Pollutant Inventory uses online reporting and allows public access to emissions data to meet statutory requirements (leading practice would involve incorporating inventory reporting requirements into GRI-based sustainability reporting).
- Some companies allow external electronic access to monitoring databases for critical stakeholders such as regulators and local community groups. This can improve transparency, although security aspects need to be considered and users must understand that raw data may contain errors.

Overall, companies are increasingly being expected to demonstrate transparency for all of their monitoring. This helps to build trust and confidence and is fundamental to the 'social licence to operate' for the members of the mining industry and the industry's collective reputation. The evidence-based benefits of enhanced reporting can be summarised as:

identification and management of key risks and opportunities, enhanced reputation among stakeholders, improved brand value, customer attractiveness, competitiveness and market position, employee attraction and retention (Bureau Veritas Group 2009) .

Sustainability reporting is essentially triple bottom line reporting, analogous to triple bottom line accounting, being an expansion of the traditional reporting framework to take into account environmental and social factors in addition to financial performance.

In the past, sustainability reports have been prepared as documents that stand alone from annual reports. As such, there is no regulatory requirement for the information and data to be assured, audited or endorsed by the board. Stand-alone reporting can be an intermediary step companies use to prepare themselves internally for the greater levels of transparency that are expected and increasingly required, in terms of both the quality and quantity of information that is made available. Leading practice can include all relevant social and environmental performance data within the annual report itself, or have separate sustainability reports signed off by the board of directors and audited, in the same way that annual reports are treated.

Leading practice reporting also encompasses disclosure of revenue earned and disbursed back to governments, especially in countries where this is not mandated or controlled through stock exchange rules. The publishing of tax and royalty payments is a crucial element in ensuring that revenues from resource and extractive industries are used responsibly by governments, as opposed to being 'lost' through waste or corruption. Guidance and standards for revenue transparency have been developed by the international Extractive Industries Transparency Initiative; details can be found at [www.eitransparency.org](http://www.eitransparency.org). The United States-based Newmont Mining Corporation has been at the forefront of such disclosure, reporting the amount of revenue paid to governments on a country-by-country basis, as opposed to aggregated reporting, which makes specific payments to governments much harder to trace and calculate (Newmont 2008).

Under the Australian Stock Exchange (ASX) listing rules, a listed entity must provide a corporate governance statement in its annual report, detailing its compliance with the ASX Corporate Governance Principles and Recommendations. While the Revised Principles contain non-mandatory obligations relating to environmental and sustainability risks, a company that does not adhere to the obligations is required to explain why in the corporate governance statement.

A company must establish policies for the oversight and management of 'material business risks' (specifically to include environmental and sustainability risks) and disclose a summary of those policies. The board should require management to design and implement a risk management and internal control system to monitor and manage the company's 'material business risks' and should disclose that management has reported the effectiveness of the company's management of such risks. A 'material business risk' is likely to include any impact of climate change, carbon pricing or environmental and sustainability legislation on the company. A listed company may limit disclosure to a summary of any policies it has which deal with such risks.

The ASX also requires the immediate disclosure of information that would reasonably be expected to have a material effect on the price or value of a company's securities. Timely disclosure must be made of information which may affect security values or influence investment decisions, and information which security holders, investors and the

ASX have a legitimate interest in. This could include information about environmental or social aspects of a mining operation that could adversely affect its production or profitability, including natural disasters, security issues and community opposition.

Leading practice dictates that monitoring of these aspects of a mining operation and reporting to the board is necessary to ensure compliance with regulatory requirements and the ASX reporting requirements for a listed entity. However, a mining company must also be cautious about the information on environmental and sustainability matters that it releases to the public, as making inaccurate, incomplete or false statements is a serious offence, especially if such statements affect the value of a mining company's securities. Therefore, seeking assurance is an important consideration.

### 4.13.2 External assurance

For many stakeholders, especially community or environmental groups, external assurance is increasingly being seen as a way to discern 'greenwash' from genuine sincerity in sustainability reports. An important aspect of this is the extent to which the provider of external assurance is allowed to audit the source data in addition to assessing the final report.

An example of this difference in approach relates to the use of riverine tailings disposal by some mines. At one unnamed site, external assurance was undertaken as part of environmental and sustainability reporting, but was effectively limited in scope to the current operational configuration. The assessor was not allowed to assess the broader impacts of such mine waste management practices, nor alternative management options. Community and environment groups are increasingly aware that a small number of mining companies are misusing sustainability reporting to justify the 'status quo' (that is, to focus solely on profitability) rather than demonstrate true changes in corporate culture and environmental, social and financial performance.

There are two primary standards for conducting sustainability assurance: ASAE 3000 *Assurance engagements other than audits or reviews of historical financial information*, which is largely used by the accountancy sector; and AccountAbility's 1000 Assurance Standard, AA1000AS (2008), available from [www.accountability21.net](http://www.accountability21.net). AA1000AS (2008) is a principle-based standard covering inclusivity, materiality and responsiveness. It provides a rigorous framework for assurance and conclusions based on evidence that reflect the status of an organisation at a particular point in time, and provides recommendations to encourage continuous improvement.

When choosing assurance based on any assurance standard, it is useful to understand what assurance based on AA1000AS (2008) offers the reporting organisation, what the process involves and how to prepare for assurance. This guidance is aimed specifically at reporting organisations and covers common issues relating to assurance from a reporting organisation perspective.

In applying AA1000AS (2008), an external assurance provider evaluates a company's adherence to the AA1000 AccountAbility Principles Standard (AA1000APS (2008)), also available from [www.accountability21.net](http://www.accountability21.net), and the reliability and accuracy

of specified sustainability performance information. The evaluation is based on publicly disclosed information (typically found in corporate social responsibility or sustainability reporting) and the systems, processes and information that underpin the organisation's disclosures. The results of this process are communicated publicly in an assurance statement.

Applying AA1000AS (2008) has both external and internal benefits for an organisation. The fundamental benefit is that external, independent assurance adds credibility to an organisation's reporting. However, many organisations that use AA1000AS (2008) suggest the internal benefit can provide an equally compelling business case, especially for organisations with reporting systems that have not fully matured.

### **4.13.3 Greenhouse gas emissions and energy monitoring**

Since the production of the *Best practice environmental management in mining handbook—environmental auditing* in 1996, a new category of emissions which require data collection, monitoring and reporting has emerged. The monitoring and reporting of greenhouse gas emissions, energy production and energy consumption by corporations is now mandated under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act).

The NGER Act requires corporations that emit greenhouse gases, or produce or consume energy above specified thresholds, to register and report their emissions, energy production and energy consumption to the Australian Government. Data collected under the NGER Act will provide the primary source of emissions data on which obligations under the Carbon Pollution Reduction Scheme will be based. Key documentation on reporting under the NGER Act includes the:

- National Greenhouse and Energy Reporting Regulations 2008
- National Greenhouse and Energy (Measurement) Determination 2008
- National Greenhouse and Energy Reporting Guidelines.

Information about the reporting obligations of corporations under the NGER Act is available from the Australian Government Department of Climate Change (at [www.climatechange.gov.au/reporting](http://www.climatechange.gov.au/reporting)).

While the best and most cost-effective method of reducing the total emissions profile of a company is to introduce abatement measures, in the interim there are several offset options available, with a national carbon offset standard currently being developed. There is a range of credible carbon offset 'standards', and advice should be sought from the Department of Climate Change about the relative merits of particular standards.

The National Greenhouse and Energy Reporting System (NGERS), established by the NGER Act, represents leading practice in monitoring and reporting of greenhouse gas emissions and energy in Australia. As well as being underpinned by legislation, NGERS is based on international reporting standards and methods, such as the World Business Council for Sustainable Development's Greenhouse Gas Protocol, and methods prescribed by the Intergovernmental Panel on Climate Change.

The NGER Act also contains a series of auditing, compliance, and enforcement provisions, which are designed to ensure that data reported under NGERS are accurate. The National Greenhouse and Energy Reporting Guidelines contain a step-by-step guide for corporations on how they may register and report under the NGER Act. Other relevant industry guidance for reporting can be found at the website for the Carbon Disclosure Project, [www.cdproject.net/](http://www.cdproject.net/).

#### **4.14 Review of monitoring programs**

As noted earlier, monitoring is the means by which mining companies and stakeholders can assess the effectiveness of management measures, verify or adjust predictions made early in the project, and develop improved management practices. With this in mind, leading practice monitoring should be regularly reviewed in the light of changes, to ensure that objectives are being met. These changes may be internal (adjustments within the organisation or operation) or external (broader regional or community adjustments).

Examples of changes that should trigger a review of monitoring programs may include:

- changes to the mine plan (for example, expansion or contraction of an operation)
- changes in the type of mining (for example, from open-cut to underground) or in the ore mined and processed on the site (for example, from oxide to sulphide)
- extreme events that may cause the company to adjust the assumptions upon which planning has been based and risk assessed
- a significant incident at another mine site of a similar type or in the same region (for example, deaths of flora and/or fauna, or community health impacts)
- changes within a community as a mine matures through its life-cycle (for example, community stabilisation following periods of substantial population expansion).

Importantly, the findings of monitoring programs should be used to inform and, if necessary, modify management decisions and practices.



## CASE STUDY: Upgrading monitoring systems to inform water management

The Ranger uranium mine, operated by Energy Resources of Australia (ERA) Ltd, is situated east of Darwin in the Northern Territory and is surrounded by the World Heritage-listed Kakadu National Park. The heritage listing occurred between 1981 and 1991, after the establishment of the operation in 1979.

The climate of the area is tropical monsoonal, with an average rainfall of about 1,600 millimetres per year, mainly falling in the 'wet season' between October and April. The concentration of heavy rains over a relatively short period of time presents a significant challenge to the operation in terms of managing its water inventory to ensure that release of water from the site does not compromise natural and cultural values, and that the downstream environments of Kakadu National Park remain protected.

In the past, the release of site catchment runoff water (not process water or seepage water from mineralised material) was permitted, depending on results from routine weekly grab samples, biological testing in specific cases, and a conservative predictive model designed to assess suitability of release conditions. While successfully protecting the environment, this approach to water management resulted in significant amounts of water unnecessarily being stored on site and subsequently requiring further treatment. The efficiencies that could be realised by using a real time monitoring system, both to identify optimum opportunities for water release and to monitor responses in receiving water quality, were clear. ERA has progressively installed continuous monitoring stations at key on-site locations to enable direct reporting of data for use in real time water management decision making.

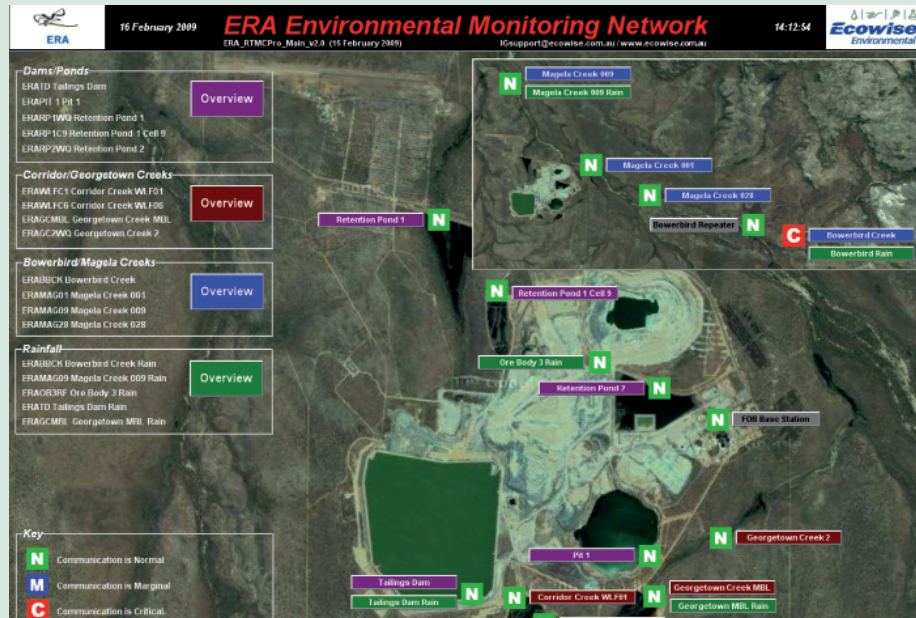
Continuous monitoring of surface water quality (for pH, electrical conductivity and turbidity) in the receiving waters of Magela Creek upstream and downstream of the Ranger mine is conducted independently by the Australian Government's Supervising Scientist Division (SSD). The Northern Territory Government conducts a regular non-continuous monitoring program in the form of water quality check monitoring to assess field parameters and laboratory testing to compare specific analyte suites against those reported by the operator. For operational purposes, this is complemented by ERA's continuous monitoring (of electrical conductivity and water levels) and grab sampling programs in the main mine site catchments.

The data from the SSD grab sampling and biological monitoring programs are posted on the SSD's website ([www.environment.gov.au/ssd/monitoring/index.html](http://www.environment.gov.au/ssd/monitoring/index.html)) to provide ongoing reporting to stakeholders and the general public on

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the protection of sensitive aquatic ecosystems. These data are used to support traditional sampling programs, with the combined datasets being used for both water management and environmental surveillance purposes.



### Energy Resources of Australia's intranet real-time environmental monitoring system.

An important attribute of the SSD's continuous monitoring network is that it provides the ability to quickly distinguish differences between the upstream and downstream environments. This allows the operator and the regulators to commence timely investigations into sources of variation, which can include natural events in the creek system and events that occur in response to inputs from the mine site. Online telemetry has been in place for several years and the assessment of the SSD's data is undertaken on a daily basis.

It is important to note that the SSD conducts a completely independent monitoring program from which data can be and are provided to stakeholders for use in water management or environmental surveillance capacities. The combined SSD, Northern Territory Government and ERA network is an example of a leading practice real time water quality monitoring system that encompasses both water management and environmental surveillance functions to ensure ongoing protection of the environment, while providing transparency for stakeholders.

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The SSD's continuous monitoring pontoon in Magela Creek downstream of the mine. The pontoon is equipped with two multiparameter (pH, electrical conductivity, turbidity) datasondes and an event-triggered autosampler. Source: Supervising Scientist Division, Department of the Environment, Water, Heritage and the Arts.



## 5.0 AUDITING

### Key messages

- Auditing is a risk management tool that can be used to review environmental and social performance against agreed audit criteria.
- Auditing is used to monitor compliance with regulatory requirements and corporate or external policies, standards and procedures.
- Auditing is a critical stage in the continuous improvement loop for sustainable management.
- There are a number of different types of environmental and social audits, the selection of which will depend on the audit objectives.
- Auditing of monitoring programs enables tracking of progress toward the achievement of environmental and social objectives.

### 5.1 Definition of an 'audit'

The internationally accepted definition of an 'audit' is based on the international standard ISO 19011:2002 *Guidelines for quality and/or environmental management systems auditing*:

An audit is a systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled.

This definition can be used for a range of audits including environmental audits, social or community relations audits and health and safety audits.

The term 'environmental audit' covers a wide range of activities based on formal evaluation of a project's performance in relation to environmental objectives. The critical elements are that the audit should be objective, systematic and based on defined criteria. These are discussed more broadly in the *Environmental audit guidebook* published by Graham A Brown & Associates and available from [www.grahamabrown.com.au](http://www.grahamabrown.com.au).

A study or survey that does not compare the current situation with agreed audit criteria cannot be called an audit.

'Internal audits', which are also called 'first-party audits', are conducted by, or on behalf of, the organisation itself, for management review and other internal purposes. In many cases, particularly in smaller organisations, independence can be demonstrated by the auditor's freedom from responsibility for the activity being audited.

'External audits' include those generally termed 'second-party audits' and 'third-party audits'. Second-party audits are conducted by parties with an interest in the organisation, such as customers (for example, a power utility that purchases coal from a coal mine), or consultants. Third-party audits are conducted by external and

independent auditing organisations, such as organisations that provide certification of conformity to the requirements of a standard (such as AS/NZS ISO 14001:2004, AS/NZS ISO 9001:2008 or AS/NZS 4801:2001); by consultants on behalf of financial institutions that are considering the provision of loan funds to a mining operation; or by independent consultants conducting a voluntary audit on behalf of an organisation (for example, an audit of a mine commissioned by its parent company).

## **5.2 Reasons for conducting an audit**

Compliance audits assess the level of compliance or performance in relation to a set standard. Information collated through compliance audits can assist in the protection of matters of environmental and social significance, and reduce the risk that serious issues will arise or compound without being detected. By demonstrating that there are systems in place to measure and improve compliance, audits also increase public confidence in the regulatory system.

Since the late 1980s, environmental auditing has become a common management tool in developed countries, and is increasingly being applied in developing countries by both foreign and local industries and by governments. It is being applied across the whole range of industrial and commercial activities, from the smallest enterprises to the largest resource projects (including mines, refineries, smelters and chemical plants), as well as government service organisations (such as transport systems and defence establishments). Social auditing is more recent and has been evolving since the early 2000s.

Environmental auditing is gradually changing in its nature and scope, and will continue to do so as environmental issues emerge and gain significance for the community, industry, commerce and governments. This leads to important changes in the environmental auditing process, and to a proliferation of different types of environmental audits to satisfy different needs, as well as the publication of numerous standards, guidelines and codes of practice for environmental auditing.

The reason for conducting an environmental audit is to assess environmental risk and establish mitigation measures to minimise that risk. An environmental audit may be conducted or required by a mining, mineral processing or refining operation; by a parent company of one of its subsidiary mines; by a lending institution financing the development or expansion of a mine; or by a government agency exercising its regulatory powers.

## **5.3 Voluntary, mandatory and statutory audits**

Environmental and social audits may be undertaken voluntarily or to meet the requirements of regulations or legislation.

'Voluntary audits' are audits that a mine conducts without compulsion from a regulatory authority and/or audits that are not required to be carried out by law. Examples of voluntary audits are environmental performance audits, compliance audits, environmental management system audits, energy audits or social audits voluntarily commissioned by an organisation. Most audits conducted by or on behalf of mining companies are voluntary environmental or social audits. In some parts of Australia (and some parts of the United States), legal privilege does, or can under specified circumstances, attach to a voluntary environmental audit report. This

means the information cannot be required to be provided to an authorised officer in the administration of the relevant Act, or by a court of law.

'Mandatory audits' are audits that are required by a regulatory consent document such as a licence, permit, consent, authority, approval, order or notice under legal powers held by the regulatory agency requiring the audit. An example of a mandatory environmental audit is a compliance audit required under a pollution control licence, to be commissioned annually by the licence holder and conducted by an independent auditor. It assesses compliance with environmental regulatory and licence conditions, and the results are reported to the regulator. Many mining environmental licences, leases, development approvals and agreements contain this condition. Self-incriminatory evidence is not exempt when included in a mandatory audit report. As there are no specific social regulatory requirements, mandatory social audits have generally not been required in consent documents; however, this condition does appear in some enabling agreements signed between a government and a mining company.

'Statutory audits' are audits that are compulsory under legislation. Examples of statutory environmental audits are compliance audits under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; industrial facility audits or site contamination audits that can be undertaken under the Victorian *Environmental Protection Act 1970*; or an 'environmental evaluation' under the Queensland *Environmental Protection Act 1994*. Statutory environmental audits may also be required under the South Australian *Environment Protection Act 1993*.

#### **What is a 'controlled action' audit?**

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, actions which are likely to have a significant impact on matters of national environmental significance must be referred to the Minister for assessment and approval. As part of the approval process, the action will be designated as one of the following types:

- controlled action
- not-controlled action
- not-controlled action—particular manner.

Approvals for projects with 'controlled action' or 'particular manner' designations contain conditions with which the project proponent must comply. The Department of the Environment, Water, Heritage and the Arts implements a program of compliance audits of such projects. The audit principles include independence of auditors, ethical conduct, fairness, and due diligence on the part of the auditors by demonstrating competence, discretion and judgment.

These audits help the Australian Government to ensure that projects impacting on matters of national environmental significance are implemented as approved. They also help to build knowledge about how well approval conditions are being understood and applied, and contribute to improving the effectiveness of the department's operations.



In New South Wales, statutory compliance audits are conducted under the compliance audit program of the New South Wales Environment Protection Authority (EPA) to assess an enterprise's compliance with environmental legislation administered by the EPA.

## 5.4 Environmental audits

Within the broad category of 'environmental audits' there are several types of audit that might apply to a mining operation.

An 'environmental performance audit' is directed at verifying a mine's environmental status with respect to specific, predetermined audit criteria. The audit program objectives should articulate senior management's and/or the board's expectations for the audit program. The audit scope should address the:

- geographic and/or business system focus of the audit
- subjects or topics to be audited
- thoroughness or depth of the audit
- scheduling and frequency of the audit
- general criteria against which the audit will be conducted and findings established.

An 'environmental management system (EMS) audit' is a specific type of environmental performance audit in which the audit scope is defined as the EMS or selected parts of it, and the audit criteria are the internal environmental policies, procedures, standards, codes of practice and so on that underpin the EMS. The EMS audit is designed to determine whether a mining operation is doing what it says it will do in its documentation of the EMS, and whether the EMS has been effectively implemented throughout the mine or that part of the mine selected for the audit. An EMS audit may assess conformance with a standard, such as ISO 14001:2004, or a mining company's specific EMS criteria (which may or may not be based on ISO 14001:2004).

A 'compliance audit' assesses a mine's compliance against selected criteria derived from legislation, regulations, licence, permit, approval, lease or other legal requirements. It may also include voluntary requirements to which the organisation subscribes, such as *Enduring value* or the *International cyanide management code for the manufacture, transport and use of cyanide in the production of gold*. Compliance audits may be statutory, mandatory or voluntary. Most multinational mining companies require periodic compliance audits to be conducted against regulatory requirements and internal policies and procedures, by either internal auditors or external auditors (or both) who report the significant results to management at the mine site and to head office. Results from multiple sites are compiled into a report for senior management and the board.

In April 2008, the Western Australian Department of Environment and Conservation introduced a condition requiring submission of annual audit compliance reports by the holders of certain licences under the *Environmental Protection Act 1986*. The compliance reports will enhance audited self-management by occupiers of prescribed

premises (including mines) and will help licensees to ensure greater compliance with their licence conditions. The department makes all the compliance reports submitted by industry publicly available.

Many audits labelled as 'energy audits' are nothing more than a generalised assessment of a mine's energy use based on tariffs or an investigation of a particular sub-system within a mine. An effective energy audit needs to examine not only the major energy end-use equipment but also the operations, maintenance and management processes of the facility and the energy sources. The energy audit is a detailed examination of how the facility uses energy, what it pays for that energy and where the energy comes from (including security of energy supply and renewable energy sources). It should result in a set of recommendations to reduce energy costs through both equipment and operational changes. A series of energy audit tools is available from the Department of the Environment, Water, Heritage and the Arts.

A 'waste audit' is essentially a study of all wastes generated by a mine; however, it may be restricted to a particular operation on a mine site, such as a coal handling and preparation plant or the mineral processing plant on a metalliferous mine. The audit must go beyond measuring the quantity of waste and identifying its composition, to identifying the underlying reasons and operational factors for waste generation, including purchasing policies and procedures; how the wastes are stored, handled and transported; and the methods of waste reuse, recycling and disposal. A mine operator may also conducted a waste audit of its waste disposal contractors, to ensure that only licensed waste disposal contractors are used, that the destination of the waste is a licensed waste disposal or recycling facility, that all waste transport and disposal is correctly documented, that record keeping complies with regulatory requirements, and that the mine is in compliance with all waste regulatory requirements.

## **CASE STUDY: Auditing to reduce waste and optimise use of by-products**

RZM Ltd operates a heavy mineral dry separation plant at Tomago in New South Wales. The plant has historically separated and sold rutile and zircon. A waste audit of the operation identified a number of waste mineral products. These were ilmenite, monazite and silica sand. The ilmenite was too high in chromium to be used for synthetic rutile production and was stored on the plant site. Monazite is a low-level radioactive mineral and at the time of the audit no market was available for its sale.

RZM Ltd had purchased land some kilometres away from the plant site with the objective of filling it with the monazite, which would have been disposed of in trenches, covered with the silica sand, and the land eventually developed as residential sections for sale. Investigations revealed that the land would be declared 'contaminated' due to the presence of the radioactive monazite. The land would therefore not be able to be used for its intended purpose of residential development. The intended 'contaminated' site was instead filled with clean fill from other sources, rezoned as industrial land and eventually developed as a light industrial estate.

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The waste audit identified that the silica sand, which had been previously classified as a waste product, was in fact a quality controlled product of 99.9 per cent purity and was in high demand for industrial use. Its designation was changed from 'waste' to 'product' and a market was rapidly established for it.

This audit process has enabled RZM Ltd to both reduce the volume of waste material generated by its operation and identify new revenue streams through the sale of the redesignated material.

'Environmental site audits' (also called 'environmental site assessments') are generally undertaken for the purposes of commercial real estate transactions, for due diligence purposes or to meet regulatory requirements, including gaining certification that a site is 'fit for use'. In many jurisdictions around the world, it is compulsory to identify contaminated sites, report their presence to regulatory authorities, register them as contaminated (or potentially contaminated), remediate them if this is necessary to protect community health and safety or environmental amenity, and certify that they are suitable for their existing, planned or potential uses. This can be a lengthy and generally expensive process, and there are many standards and guidelines relating to site assessments (see 'Further reading'). AS/NZS ISO 14015:2003 *Environmental management—environmental assessment of sites and organizations (EASO)* is the accepted international standard, and guidance information on contaminated site investigations is available from the National Environment Protection Council and most state and territory governments.

Environmental security has become a major issue worldwide. A facility that stores, uses or transports dangerous goods in significant quantities must be aware of security risks and take measures to protect the goods from malicious or accidental events that may harm the environment or human health and safety. An 'environmental security audit' is an essential part of this risk assessment, especially for mines that transport and use bulk quantities of substances such as cyanide, ammonium nitrate, acids, sodium hydroxide and certain toxic chemicals used in the processing of minerals. As well as raw materials, any materials that could cause significant harm if discharged into the environment, such as radioactive products (for example, yellowcake), mineral concentrates and wastes (for example, used oil), need to be assessed. The environmental security audit may include vulnerability assessments of critical infrastructure facilities, combined with a gap analysis of environmental, health and safety information and security management systems. The transport of dangerous substances through sensitive environments, such as wetlands, river crossings, national parks and conservation areas, towns and villages, is an essential component of the environmental security audit.

The *International cyanide management code for the manufacture, transport and use of cyanide in the production of gold* was developed as a voluntary industry code under the direction of a multi-stakeholder steering committee, whose members were chosen by the United Nations Environment Programme and the International Council on Metals and the Environment. The code encourages improvement on an industry-wide basis by aggressively promoting participation in the code, and by requiring

signatories to the code to take appropriate action to manage cyanide responsibly. The International Cyanide Management Institute was established for the purpose of administering the code.

The code focuses exclusively on the safe management of cyanide and cyanidation mill tailings and leach solutions. It addresses the production, transport, storage and use of cyanide and the decommissioning of cyanide facilities. It includes requirements related to financial assurance, accident prevention, emergency response, training, public reporting, stakeholder involvement and verification procedures. The code is composed of two major elements: the principles, which broadly state commitments that signatories make to manage cyanide in a responsible manner; and the standards of practice, which identify the performance goals and objectives that must be met to comply with each principle. Relevant documents can be viewed and downloaded from [www.cyanidecode.org/auditors\\_code.php](http://www.cyanidecode.org/auditors_code.php).

## 5.5 Social audits

Social or community relations audits are required by governments and lending institutions for major resource and infrastructure projects (for example, mining, forestry, dams, power transmission lines, roads and railways or ports), especially in developing countries and to a lesser extent in developed countries.

Social audits are often combined with environmental audits, as factors that impact on the environment often also impact on the surrounding communities. In some cases, whole villages and even tribal groups must be moved because of the extent of flooding of valleys by a major dam, or by the land requirements for a major open-cut mine and its associated facilities. In other cases, the lifestyles of Indigenous communities are disrupted, traditional agricultural practices are restricted, heritage sites are destroyed and internal migration within the country introduces new people and cultures to an area. The transport of hazardous substances such as cyanide and ammonium nitrate to a mine, or radioactive yellowcake product from a mine, may pose significant risks to both communities and sensitive environments along the transport routes.

Specific social audit protocols must be developed based on criteria sourced from a variety of documents, especially the *Equator Principles* (EPFI 2006), *Enduring value* (MCA 2004), and the World Bank International Finance Corporation's guidelines and performance standards (IFC 2006, 2007a, 2007b), that may apply to a particular mining project.

### **Performance Standards on Social and Environmental Sustainability**

The International Finance Corporation performance standards (PS) of April 2006 include the following standards.

- PS1: Social and Environmental Assessment and Management Systems
- PS2: Labor and Working Conditions
- PS3: Pollution Prevention and Abatement
- PS4: Community Health, Safety and Security
- PS5: Land Acquisition and Involuntary Resettlement
- PS6: Biodiversity Conservation and Sustainable Natural Resource Management
- PS7: Indigenous Peoples
- PS8: Cultural Heritage.

## **5.6 Specific subject audits**

An organisation may decide to undertake an environmental or social audit on a specific operation or part of a mine, or an affected community, for a variety of reasons, such as ensuring compliance, improving efficiency, effecting cost savings or reducing risk. These audits may be of any aspect of the company's own mining operations, the on-site or off-site operations of contractors for whose environmental, safety and community relations performance the company is legally responsible, or the operations of waste contractors and external waste disposal and recycling facilities. This is often important during the exploration phase of a project, when earthmoving and drilling contractors may be operating over a wide area with little corporate supervision.

## **CASE STUDY: Using audits for self-improvement of rehabilitation outcomes**

Xstrata Coal has developed and implemented an audit process entitled Mine Rehabilitation Review to assess and report on the status of rehabilitation practices at all its operating mines. The process is designed to enable operating mines to undertake a self-assessment review on an annual basis, complemented by a third-party assessment undertaken every three years.

Results are collated and reported to the Xstrata Coal Executive Sustainable Development Committee, which helps to benchmark rehabilitation performance across the group. Recommendations from the review at each site are required to be entered into Xstrata Coal's database system, which tracks progress of the implementation of required actions, thereby enhancing accountability within the organisation.

The key elements of the Mine Rehabilitation Review are:

- **Rehabilitation Systems**—This includes a qualitative ranking protocol developed to assess current performance in relation to setting final land use objectives and criteria; undertaking pre-mining baseline and/or reference site monitoring; using biological resources to enhance rehabilitation; integration of rehabilitation into the mine planning process; implementation of rehabilitation practices; and implementation of effective rehabilitation monitoring programs.
- **Rehabilitation Performance**—This includes an on-the-ground assessment of performance against the agreed final land use. The highest ranking denotes that rehabilitation objectives are verified by monitoring. Among the key issues assessed are soil profile development; resistance to erosion; floral structure, health and diversity; fauna recolonisation; evidence of ecosystem resilience; pasture species diversity; and weed infestation.
- **Meeting Rehabilitation Criteria**—This section is intended to be the key driver for rehabilitation performance across the Xstrata Coal group. A score in this section requires that closure criteria have been established, and a robust monitoring program is in place to assess performance in relation to meeting defined criteria and targets. For rehabilitated areas over five years old, percentage compliance is assessed for cover; vegetation species; fauna; and area eroded. Areas needing maintenance (such as refertilising, supplementary planting or weed control) are identified for corrective action.
- **Rehabilitation Progress**—This section provides an understanding of the current rehabilitation liability across the group. Key parameters include total disturbed and rehabilitated areas as well as dump reshaping progress.

This process has enabled Xstrata Coal to monitor and track rehabilitation performance. As well as promoting continual improvement across the group, it enables sites to develop suitable rehabilitation care and maintenance programs and facilitate progressive sign-off of rehabilitation.

Many mining and petroleum operations develop integrated management systems, which may include environment, health and safety, security, community relations and other aspects, such as planning and construction or financial accounting. Some examples are Anglo Coal's Safety, Health, Environment and Community Management System, BP's Getting HSE Right, Atlantic Richfield Oil Company's Operating Excellence System, BHP Billiton's Health, Safety, Environment and Community Management System and the Oxiana Integrated Management System (OXims) used by Minerals and Metals Group (formerly Oxiana). These systems may be audited regularly by internal auditors, or by external auditors commissioned by the company. In some cases they are audited by the lending institutions funding mining operations.

## **CASE STUDY: Auditing against corporate standards**

Minerals and Metals Group (MMG) undertakes audits of its operations using the Oxiana Integrated Management System (OXims) audit program, to improve its sustainability performance. Sites are assessed against the company's health and safety, environment, social and integrated management systems standards, identifying gaps or weaknesses that require action to manage risk, and opportunities for improvement.

The approach is based on the following principles:

- audits are viewed as part of the risk management and continuous improvement cycle, rather than as a pass/fail or compliance system
- qualified, experienced and independent auditors lead the audits
- audits are relevant to site issues and risks
- audit outcomes are clearly communicated to the management team at a face-to-face meeting and through a report
- action plans are prepared and implemented as part of the operation's improvement planning process.

The audit outcomes help to fulfil MMG's social and environmental obligations (including legal and contractual obligations), as well as MMG's voluntarily imposed standards of practice and behaviour as defined by the OXims standards. The OXims standards are applicable to all phases of mine life (including exploration, scoping, feasibility and project design; construction; operation; closure; and post-closure monitoring). The standards provide direction to project teams, operations personnel and technical specialists.

The audit outcomes also highlight to the Executive Committee and Board any material deficiencies or risks that could impact significantly on the reputation or financial strength of the business from a social and environmental responsibility perspective. Importantly, this type of audit also integrates the areas of health, safety, environment and community into mainstream business processes and decision making.

## 5.7 Audit personnel

Environmental and social audits can be conducted by internal or external auditors. The definition of an auditor in ISO 19011:2002 is 'person with the competence to conduct an audit'. The level of competence required for an audit is a decision for management of the organisation commissioning the audit.

All members of an audit team, or the lead auditor only, may be required to be certified as an environmental auditor by an accredited personnel certification body such as RABQSA International ([www.rabqsa.com](http://www.rabqsa.com)). Most organisations will require their external auditors to be certified by a recognised body, not necessarily in Australia. For example, certification is available through the Institute of Environmental Management and Assessment in the United Kingdom and the Board of Environmental Auditor Certifications in the United States. There is currently no certification available specifically for a social auditor.

Members of the audit team may also be required to have undertaken an internal auditor training course approved by management and in accordance with the organisation's own procedures.

## 5.8 Audit plan

An environmental or social audit should be carried out by competent auditors following an audit plan that incorporates an agreed environmental audit protocol.

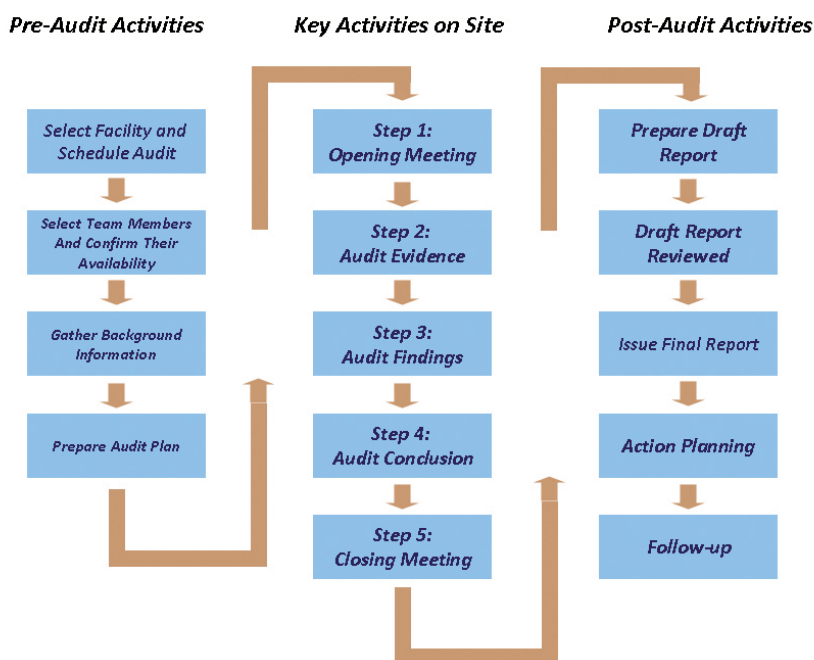
The audit plan should include, if applicable, the:

- name and position of the auditee's representative
- audit objectives and scope
- audit criteria
- organisational and functional units to be audited
- functions and/or individuals within the auditee's organisation that have significant direct responsibilities regarding the audit
- elements of the auditee's environmental and/or social management programs that are of high audit priority (based on risk)
- procedures for auditing the auditee's management program elements, as appropriate for the auditee's organisation
- working and reporting languages of the audit
- details of reference documents
- expected time and duration for major audit activities
- dates and places where the audit is to be conducted
- names of audit team members
- schedule of meetings to be held with the auditee's management

- report confidentiality requirements
- report content, format and structure
- expected date of issue and distribution of the report
- document retention requirements.

A detailed audit plan will provide a format for assigning specific tasks to individual members of an audit team, for comparing what was accomplished during the audit with the original audit plan, and for summarising and recording the work in progress and work completed.

An environmental or social audit is generally carried out in three phases—pre-audit activities, site activities and post-audit activities—as shown in the diagram below.



Source: Graham Brown, Graham A Brown & Associates.

## 5.9 Audit protocol

The environmental or social audit protocol presents a process for the auditor to follow to accomplish the objectives of the audit. This process may be a standard procedure, or it may be a guideline specific to the organisation or facility being audited.

Using a comprehensive audit protocol ensures consistency in the audit process and reporting procedures. This is particularly important where audit teams are used and where members of those teams may be selected on a rotating basis. An audit protocol can also be used to help train inexperienced auditors and to reduce the amount of supervision required by the leader of the environmental audit team.



Audit protocols can be general, or they can be specific to a particular audit type or to the mine site being audited. The criteria agreed for the audit should be reflected in the audit protocol. This enables the auditor to assess the level of conformance by the mine site with the criteria by using the audit protocol.

Audit protocols may incorporate a rating system or other numerical process for evaluating the results of an audit. This can be valuable in comparing the environmental or social performance of one mine with the performance of others, and for tracking improvement (or decline) over time.

## 5.10 Audit evidence

Only evidence that is verifiable is accepted as audit evidence. Audit evidence is verified by a combination of:

- review of documentation, the highest standard of verification
- observation of activities or situations, a lower standard of verification
- interview of appropriate personnel, the lowest standard of verification.

In general, audit evidence will be persuasive rather than conclusive. It is necessary for the auditor to use professional judgment to evaluate the audit evidence and determine whether sufficient inquiry has been undertaken. If firm conclusions cannot be drawn from the evidence available, it may be necessary to qualify the audit report accordingly.

## 5.11 Audit report

The contents of the environmental or social audit report will depend on the type of audit being carried out and what is agreed between the auditor and the management commissioning the audit. Some audit reports of mine sites will be very detailed; others will report only exceptions, that is, only instances where the audit findings do not meet the agreed audit criteria.

Audit reports may include recommendations (which is common for external audit reports) or, in the case of internal and management systems audits, they may only report non-conformances with internal policies, procedures and standards, or non-compliances with regulatory requirements. Recommendations may be graded (for example, emergency, urgent, improvement or normal) and non-conformances may be ranked (for example, major, minor, improvement or observation). The auditor may be required to verify at a later date that recommendations have been addressed, or that non-conformances have been subjected to corrective and/or preventive action.

**Contents of a typical environmental audit report under the  
*Environment Protection and Biodiversity Conservation Act 1999***

1. Audit objective
2. EPBC Act controlling provisions
3. Audit findings
  - 3.1 Compliance
  - 3.2 Non-compliance
  - 3.3 Undetermined
  - 3.4 Observations
4. Recommendations
5. Audit process
6. Terminology
7. Attachment A–approval notification–EPBC 2001/x
8. Final report distribution

## **5.12 Assurance**

The level of inquiry or assurance applicable to an environmental or social audit will depend on the type of audit being conducted, the authority for the audit (internal, external, voluntary, mandatory and/or statutory) and an organisation's internal auditing standards or statutory requirements.

ISO 19011:2002 provides guidance on this subject; however, there are a number of other guidance documents or required standards that can be useful for audits in or of the mining industry. These include ASAE 3000 *Assurance engagements other than audits or reviews of historical financial information 2007* and ASAE 3100 *Compliance engagements 2008*, issued by the Australian Government's Auditing and Assurance Standards Board; guidance information on contaminated site investigations from the National Environment Protection Council and most state and territory governments; and the 'all appropriate inquiry' regulation issued by the United States Environmental Protection Agency in Subtitle B of Title II of the Small Business Liability Relief and Brownfields Revitalization Act 2002.

With regard to environmental and social audits, 'materiality' relates to the extent to which the auditor believes that the report could be mis-stated and still not affect the decisions of reasonable users. Consideration of materiality assists in planning an efficient and effective audit, as trivial items can be ignored and the audit procedures can be conducted in areas considered to be of higher importance, providing a greater level of assurance.



## 6 CONCLUSIONS

Evaluating performance is an essential component of leading practice sustainable development in mining. Monitoring and auditing are the tools companies use for evaluating and improving performance in relation to meeting their objectives for the protection and re-establishment of environmental, social and economic values. Companies recognised for their leading performance fulfil regulatory requirements consistently and on time, but also frequently go beyond the minimum requirements for monitoring and auditing. This handbook describes how companies use monitoring and auditing to achieve their sustainable development goals.

Leading practice monitoring design is based on accepted risk management procedures and sound scientific principles, with mine closure and the agreed end use of the land in mind. It focuses on all aspects of sustainable development: environmental, social, socioeconomic, cultural and spiritual. Monitoring programs are designed in consultation with all interested stakeholders, with the involvement of community groups, non-government organisations and others helping to ensure that all key elements and issues are covered. Techniques used include the best available methods, with staff safety a primary consideration. Monitoring links to research by identifying areas for further investigation and assessing the effectiveness of new procedures.

Monitoring programs are transparent, with data provided to stakeholders through appropriate reporting procedures, which in some cases might include online access to real time air or water quality monitoring data. Independent external assurance is increasingly used to verify the quality and accuracy of reporting. Monitoring programs are regularly reviewed to ensure their current relevance, by taking into account changes in mine plans, legislation, community circumstances, monitoring technology or any other relevant aspects.

Auditing provides a check on performance by comparing the current situation with agreed audit criteria. Internal audits are conducted by companies for management review and related purposes. External audits are conducted by parties external to the organisation, for example, where independent verification of performance is required. There is a variety of different types of audits, which may be compulsory or voluntary. All audits are based on agreed protocols and audit criteria. They may be designed to assess compliance with regulatory requirements, or performance in relation to implementing environmental and social procedures and management systems, or meeting defined standards. Commonly, the reason for conducting an environmental or social audit is to assess risk and establish mitigation measures to minimise that risk. The type of reporting will vary depending on the type of audit and its purpose; however, voluntary independent audits are increasingly being used to communicate performance to external stakeholders.

Together, monitoring and auditing are used to develop completion criteria and confirm that associated targets and milestones have been met.

Overall, the leading practice approach to monitoring can be summarised as follows. Regardless of the size of a mining operation, a risk-based approach is recommended to ensure that site-specific monitoring programs incorporate appropriate monitoring elements, parameters, frequencies and applicable performance criteria on which to assess the monitoring data.



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## Glossary and abbreviations list

Artisanal mining	Small-scale mining involving the extraction of minerals using simple tools and equipment, usually on a subsistence level
ASX	Australian Stock Exchange
BACI	before-after-control-impact
EIA	environmental impact assessment
EMS	environmental management system
<i>Enduring value</i>	<i>Enduring value: the Australian minerals industry framework for sustainable development</i>
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
ESIA	environmental and social impact assessment
GIS	geographic information system
GPRS	general packet radio service
GPS	global positioning systems
Greenwash	The dissemination of misleading information by an organisation to conceal poor environmental performance and present a positive image
GRI	Global Reporting Initiative
ICMM	International Council on Mining and Metals
MCA	Minerals Council of Australia
NGER Act	<i>National Greenhouse and Energy Reporting Act 2007</i>
NGERS	National Greenhouse and Energy Reporting System
OHS	occupational health and safety
PPE	personal protective equipment
REACH	European Commission Regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals
SEIA	socioeconomic impact assessment
TSF	tailings storage facility

## Further reading

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Heritage and the Arts

<http://www.environment.gov.au/about/legislation.html>

#### NSW

Department of Environment and  
ClimateChange

<http://www.environment.nsw.gov.au/legislation/>

#### Vic.

Environment Protection Authority

<http://www.epa.vic.gov.au/publications/>

#### Qld

Environment Protection Agency

[http://www.epa.qld.gov.au/about\\_the\\_epa/legislation/](http://www.epa.qld.gov.au/about_the_epa/legislation/)

#### WA

Environmental Protection Authority

<http://www.epa.wa.gov.au/template.asp?ID=10&area=Profile&Cat=Legislation>

#### SA

Environment Protection Authority

<http://www.environment.sa.gov.au/epa/legislation.html>

#### Tas.

Department of Environment, Parks, Heritage  
and the Arts

<http://www.environment.tas.gov.au>

#### ACT

Department of Territory and Municipal  
Services

<http://www.tams.act.gov.au/live/environment>

#### NT

Department of Natural Resources,  
Environment, The Arts and Sport

<http://www.nt.gov.au/nreta/environment/>

### Legislation

ComLaw

<http://www.comlaw.gov.au>

NSW Parliamentary Counsel's Office

<http://www.legislation.nsw.gov.au/maintop/scanact/inforce/NONE/O>

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<http://www.arpansa.gov.au/Publications/Codes/rps1.cfm>

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### International Organization for Standardization standards

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- ISO 14004:2004 provides guidance on the development and implementation of environmental management systems
- ISO 14020:2000 covers labelling issues
- ISO 14030+ provides guidance on performance
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## Appendix 1

### Ten principles of sampling

The ten principles of sampling were defined by RG Green in 1979 (*Sampling design and statistical methods for environmental biologists*, John Wiley & Sons, New York). Although this is an old reference, the principles of sound experimental design have not changed, and it is worth restating them because companies and their advisers still occasionally design and undertake monitoring programs that are not suited to rigorous analysis and unequivocal interpretation of the findings. Leading practice requires that the ten principles be taken into account when designing quantitative monitoring programs. More detail on experimental design is provided in Section 3.2.2.

1. Be able to state concisely to someone else what question you are asking.
2. Take replicate samples within each combination of time, location and any other controlled variables. Differences among sites can only be demonstrated by comparison with differences within sites.
3. Take an equal number of randomly allocated replicate samples for each combination of controlled variables. Sampling in 'representative' or 'typical' places is NOT random sampling.
4. To test whether a condition has an effect, collect samples both where the condition is present and where the condition is absent but all else is the same. An effect can only be demonstrated by comparison with a control.
5. Carry out some preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options.
6. Verify that your sampling device is sampling the population that you think you are sampling, and with equal and adequate efficiency over the entire range of sampling conditions to be encountered (e.g. aquatic invertebrates).
7. If the area to be sampled has a large scale pattern, break the area up into relatively homogeneous subareas and allocate samples to each in proportion to the size of the subarea ('stratification').
8. Verify that your sample unit size is appropriate to the size, densities and spatial distributions of the organisms you are sampling. Then estimate the number of replicate samples required to obtain the precision you want.
9. Test your data to determine whether the error variation is homogeneous, normally distributed and independent of the mean. If it is not, as will be the case for most field data, then (a) appropriately transform the data, (b) use a distribution-free (nonparametric) procedure, (c) use an appropriate sequential sampling design, or (d) test against simulated null hypothesis (Ho) data.
10. Having chosen the best statistical method to test your hypothesis, stick with the result. An unexpected or undesired result is NOT a valid reason for rejecting the method and hunting for a 'better' one.

## Appendix 2

### Typical elements of a monitoring and performance evaluation program

Table A1: Typical environmental elements of a mining project's monitoring and performance evaluation program

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
<b>General</b>					
Site inspections/facility audits	Water, soils/erosion, land clearance, flora/fauna, noise, air quality, hazardous materials and general waste management	Weekly	Weekly	Quarterly/yearly	Commitments specified in site Environmental Management Plan.
Meteorology	Rainfall, evaporation <sup>c</sup> , temperature, solar radiation, wind speed, wind direction, relative humidity etc.	Daily/continuous	Daily/continuous	Daily/continuous (remote)/as required	n/a
Hydrology—upstream and downstream of site	Flow rate (discharge) <sup>d</sup> , water level	Daily/continuous	Daily/continuous	Daily (remote)/as required	Minimal alteration of downstream hydrology.
Sediment transport/geomorphology—upstream and downstream of site	Erosion and sediment transport rates (fluvial <sup>e</sup> and/or aeolian processes), composition, geomorphology (visual; surveyed cross-sections/profiles; remote sensing; digital terrain modelling)	Baseline	Quarterly/ half-yearly (seasonal)/yearly/ event-based	Quarterly/yearly	n/a
Surface water quality—upstream and downstream of site	General water quality parameters (field) <sup>f</sup>	Quarterly	Daily/weekly/event-based	Quarterly/yearly	State/national water quality guidelines for ambient surface water/ drinking water (e.g. ANZECC & ARMCANZ 2000; NHMRC 2004). Baseline and upstream. Collaboration with other stakeholders recommended for reference data collection if required.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/ feasibility phase <sup>b</sup>	Construction/ operations phase	Closure/post-closure phase (e.g. 3+ years)	
Surface water quality— upstream and downstream of site	General and detailed water quality parameters (laboratory) <sup>9</sup>	Quarterly	Weekly/monthly/ event-based	Quarterly/yearly	State/national water quality guidelines for ambient surface water/ drinking water (e.g. ANZECC & ARMCANZ 2000; NHMRC 2004). Baseline and upstream. Collaboration with other stakeholders recommended for reference data collection if required.
		Monthly/quarterly	Weekly/monthly	Quarterly/yearly	
Hydrogeology—upgradient and downgradient of site (including public/private water supply bores)	General water quality parameters (field) <sup>7</sup>	Monthly/quarterly	Weekly/monthly	Quarterly/yearly	State/national water quality guidelines for groundwater/drinking water. Baseline and upgradient data.
	General and detailed water quality parameters (laboratory) <sup>9</sup>	Quarterly/yearly	Monthly/quarterly	Quarterly/yearly	Sufficient but not excessive volume of water on site.
Site water balance	Flow rates/pump rates	Baseline	Daily	n/a	No evidence of significant increase in acidity, salinity or contaminant loads over time associated with the project.
	Water levels and volumes in storage facilities	n/a	Daily	Daily (remote)/ as required	
Site acidity/salinity/ contaminant load balance	Site water balance (see above)	See above	See above	See above	
	Acidity/salinity/contaminant concentrations	Baseline	Weekly/monthly/ quarterly	Daily (remote)/ as required	

(continued)



Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Discharge water	Flow rates, water levels	n/a	Continuous/ daily/ event-based	n/a	State/national/ international water quality guidelines for discharge water (e.g. IFC 2007a). Mixing zones important.
	General water quality parameters (field) <sup>f</sup>	n/a	Continuous/ daily/ event-based	n/a	
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Monthly/quarterly/ event-based	n/a	
Drinking water supply (project site and potentially affected communities)	General water quality parameters (field) <sup>f</sup>	Baseline/weekly	Weekly	Quarterly/yearly	State/national/ international water quality guidelines for drinking water (e.g. NHMRC 2004; WHO 2004).
	General and detailed water quality parameters (laboratory) <sup>g</sup>	Baseline/Monthly/ quarterly	Monthly/quarterly	Quarterly/yearly	
Terrestrial ecosystems (e.g. revegetated waste rock pile covers, other rehabilitated areas, reference sites); groundwater ecosystems	Indicators of ecosystem health, diversity and sustainability, extent of vegetation cover/ cleared land, dieback/tree decline or bare patches (if any), diversity of flora, indicator fauna species (e.g. mammals, avifauna, invertebrates, stygofauna), feral animals, mosquito/health risk vectors, soil/plant pathogens, abundance of weeds, bushfire risk/control measures; human food chain indicators (e.g. bush tucker, fish, crustacean, mammals), refer to biodiversity management and mine rehabilitation handbooks	Baseline	Half yearly/ yearly	Half yearly/ yearly	Baseline and reference site data on natural ecosystems and rehabilitated areas.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Riparian ecosystems—reference and impact sites (ambient)	Indicator species of riparian flora/fauna—determine if groundwater/baseflow dependent ecosystem (GDE) (ground and surface water monitoring as well as water use by plants to determine if dependent upon baseflow or other water sources)	Baseline/seasonal (late dry season to determine water source(s) used by potential GDEs)	Seasonal	Seasonal	Baseline and reference site data. Target set by groundwater extraction rates for drawdown or other potential impact and monitored signs of tree stress/decline.
Aquatic ecosystems—reference and impact sites (ambient)	Indicator species (e.g. algae, micro/ macroinvertebrates, fish, other vertebrates); refer to biodiversity management handbook	Baseline; Monthly/yearly (taxa and ecosystem specific)	Monthly/yearly (taxa and ecosystem specific)/ event-based	Half-yearly (seasonal)/ yearly	Reference site aquatic fauna/flora.
Aquatic ecosystems—direct toxicity assessment	Indicator species (e.g. algae, macroinvertebrates, fish, larger vertebrates); refer to biodiversity management handbook	As appropriate for pilot plant/ bench test effluents	As required	As required	Trigger value as determined by ANZECC & ARMCANZ (2000) procedures.
Aquatic ecosystems—environmental flows	Flow regime alteration (see above—Hydrology)	Baseline (hydrology; flow dependency of aquatic and riparian biota)	See above (hydrology, aquatic and riparian ecosystems)	See above (hydrology, aquatic and riparian ecosystems)	Minimal alteration of flow regime, particularly base flows and timing and frequency of peak flow events. Flow dependent ecosystem status. Minimal alteration of organism distributions.
Aquatic ecosystems—organism passage	Passage design and operation; organism passage and persistence upstream and downstream	Baseline (passage requirements of aquatic and riparian biota)	Yearly/event-based	Yearly/event-based	Minimal alteration of organism distributions. Organism passage rates unchanged.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Soils (including soil cover materials)	General chemical parameters (e.g. pH, electrical conductivity), composition, geochemical classification <sup>1</sup> , moisture content, porosity, permeability, structure, texture, organic matter content, soil erosion, soil biota, stockpile quantities, quality and longevity, extent/nature of contamination	Baseline	As required for rehabilitation planning/water quality control	Quarterly/yearly	n/a
Grazing animals–baseline and reference sites	Carrying capacity of paddocks, grazing trials, pasture production, weeds and pests	Baseline	Yearly (seasonal)	Yearly (seasonal)	Targets set as part of post-mining land use for grazing (community requirement/ condition of mining lease).
Intensive agriculture/horticulture–baseline and reference sites	Crop production/biomass, soil quality, erosion (e.g. alluvial areas); soil chemistry and physical properties (see above–Soils)	Baseline	Seasonal (crop cycles)	Seasonal (crop cycles)	Production targets for post-mining land use (agreed pre-mining).
Ambient noise–control sites, sensitive receptors and on site	Noise (e.g. A-weighted decibels)	Baseline	As required/during selected blasts.	n/a	State/national/international guidelines (e.g. IFC 2007b)
Ambient air quality– control sites, sensitive receptors and on site	Depositional dust (e.g. rate of deposition, composition), suspended dust (e.g. PM <sub>10</sub> )	Baseline	As required/during selected blasts.	n/a	Baseline and upwind data.
Energy consumption	Airborne contaminants (e.g. sulphur dioxide, nitrogen oxide, PM <sub>10</sub> , carbon monoxide) Direct energy consumption (fuels); indirect energy consumption (electricity)	Baseline	Monthly/quarterly	n/a	State/national/international guidelines (e.g. IFC 2007b).
		Baseline	Yearly	n/a	Baseline data. Production efficiency/energy use ratio is maintained or improved.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Greenhouse gas emissions	Direct emissions from power stations/smelters (see below) and vehicles/machinery/plant used on site (carbon dioxide equivalent.)	Baseline	Yearly	n/a	Baseline data. Production efficiency/emissions ratio is maintained or improved.
	Indirect emissions associated with electricity use (carbon dioxide equivalent)	Baseline	Yearly	n/a	
Hazardous material consumption	Rate of hazardous material consumption (process chemicals, explosives etc.); refer to hazardous materials management handbook	Monthly/quarterly	Monthly/quarterly	n/a	n/a
	Rate of hydrocarbons consumption (fuels, oils, lubricants etc.)	Monthly/quarterly	Monthly/quarterly	n/a	
Radiation	Radon emanation and gamma radiation from ore stockpiles, tailings mass and rehabilitated tailings impoundment, radiologically contaminated waste disposal sites for scrap metal etc, radionuclide mobility in drainage (to surface and groundwaters), radionuclides in airborne dust; this applies to all industries working with naturally occurring radioactive material (NORM), not just uranium, thorium and mineral sands OHS measures.	Environmental baseline from pre-mining survey data. Operational baseline from pilot plant, trial plots, lab-based samples and modelling.	Frequent early (to verify model data), then adjust according to variations in ore grade/ composition and changes in operations/ technology used (e.g. include ventilation outlets if underground operations commence).	Frequency depends on parameter (e.g. immediately post operations/ residue containment, frequency may be continuous for radon) and authorisation, often half yearly or seasonal.	Radiological standards. Radiation safety and OHS and environmental monitoring all to be integrated.

(continued)

Element	Parameters			Indicative frequency <sup>a</sup>			Performance evaluation criteria
	Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)				
Emergency response (e.g. spill) – location of emergency; receiving environment (e.g. surface water, groundwater, soil)	General water quality parameters (field) <sup>i</sup>	Event-based	Event-based	Minimal risk to receiving environment.			
	General and detailed water quality parameters (laboratory) <sup>9</sup>	Event-based	Event-based				
	Extent/nature of soil contamination	Event-based	Event-based				
Environmental/social safety <sup>i</sup>	Ecosystem impacts (e.g. terrestrial/groundwater/riparian/aquatic ecosystems)	As required	n/a	Environmental/social safety risks minimised.			
	Geotechnical hazards (e.g. landslip, collapse), natural hazards (e.g. bushfire, storm, flood, earthquake, extreme heat/cold); chemical, biological (e.g. fungus) or radiological hazards; personal exposure/ambient (e.g. oxygen, carbon dioxide, methane, hydrogen sulfide, temperature, smoke, dust, illumination)	As required	n/a				
<b>Waste rock and ore stockpiles</b>							
Waste rock and ore material	Waste rock and ore production rates, mass/volume of waste rock piles (including location/amounts of different waste rock materials) and ore stockpiles	Modelled predictions	Daily	n/a	Modelled data.		
	Geochemical characterisation of lithologies <sup>h</sup>	Baseline/ as required	As required	As required	Geochemical condition not threatening rehabilitated landscape or downstream ecosystems.		
Hydrology (surface runoff and seepage)	Flow rates (surface runoff, surface seepage), water levels	n/a	Weekly	Quarterly/yearly	n/a		

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Water quality (surface runoff and seepage)	General water quality parameters (field) <sup>f</sup>	n/a	Weekly	Quarterly/yearly	Baseline and upstream data. Predicted water quality.
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Monthly	Quarterly/yearly	
Hydrogeology (water in waste rock piles; groundwater upgradient, beneath and downgradient of piles)	Infiltration rates and moisture content in waste rock piles (pore pressure/hydraulic/lysimeter data)	n/a	Quarterly	As required	Target/design infiltration rates.
	Water levels; volume of pore water in waste rock piles; mass/volume of waste rock exposed to oxygen	n/a	Monthly	Quarterly/yearly	n/a
Geotechnical stability	Geophysical survey (e.g. time domain electromagnetic; resistivity) to map sub-surface conductivity and seepage flow pathways	As required	As required	As required	n/a
	General water quality parameters (field) <sup>f</sup>	n/a	Monthly	Quarterly/yearly	State/national guidelines for groundwater quality. Baseline and upgradient.
Geotechnical stability	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Quarterly	Quarterly/yearly	Engineering design specifications; rehabilitation objectives.
	Erosion, subsidence, landslips, water levels (see above)	n/a	Daily/weekly	Yearly/as required	
<b>Tailings storage facilities, tailings dams</b>					
Tailings material	Milling and tailing production rates, mass/volume transferred to tailings storage facilities	Modelled predictions	Weekly	n/a	Modelled data.
	Geochemical characterisationh	Baseline/as required	As required	n/a	Geochemical condition not threatening rehabilitated landscape or downstream ecosystems.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Hydrology (supernatant water)	Volume, water level, flow rate of tailings into facility, flow rate of decant pumps, spillway flow rates	n/a	Daily	Daily (remote)/as required	n/a
	Flow rate, water level	n/a	Weekly/monthly	Daily (remote)/as required	n/a
Water quality (supernatant water and surface seepage)	General water quality parameters (field) <sup>f</sup>	n/a	Weekly	Quarterly/yearly	Site-specific water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Monthly	Quarterly/yearly	
Hydrogeology (pore water in tailings; groundwater upgradient, beneath and downgradient of tailings storage facilities)	Water levels; mass/volume tailings exposed to oxygen	Baseline	Monthly	Quarterly/yearly	n/a
	Geophysical survey (e.g. time domain electromagnetic; resistivity) to map sub-surface conductivity and seepage flow pathways	As required	As required	As required	n/a
Fauna	General water quality parameters (field) <sup>f</sup>	Baseline	Monthly	Quarterly/yearly	State/national guidelines for groundwater quality. Baseline and upgradient data.
	General and detailed water quality parameters (laboratory) <sup>g</sup>	Baseline	Quarterly	Quarterly/yearly	
	Avifauna, mammals, livestock	Baseline	Weekly; event-based	Yearly	No evidence of project-related fauna deaths.

(continued)



Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Geotechnical stability (embankment/dam wall; tailings)	Erosion, subsidence, landslips, supernatant and groundwater levels (see above); tailings density, strength (penetrometer) and water content (water liberated by consolidation and ability to support a cover if required); refer to tailings management handbook	Modelled predictions	Daily/weekly/ event-based	Yearly/as required	Engineering design specifications; rehabilitation objectives.
<b>Pits/open cuts</b>					
Pit wall material (groundwater cone of depression)	Mass/volume of material exposed to oxygen	Modelled predictions	As required	As required	Modelled data.
	Geochemical characterisation of lithologies <sup>h</sup>	Baseline/ as required	As required	As required	Geochemical condition not threatening rehabilitated landscape or downstream ecosystems.
Pit hydrology/ stormwater	Dewatering pump flow rates	Modelled predictions	Daily	As required	n/a
	General water quality parameters (field) <sup>i</sup>	Modelled predictions	Weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
Pit hydrogeology (groundwater cone of depression)	General and detailed water quality parameters (laboratory) <sup>9</sup>	Modelled predictions	Monthly	Quarterly/yearly	Modelled data.
	Groundwater levels, flow rates (e.g. dewatering bores)	Modelled predictions	Weekly	Quarterly/yearly	Modelled data.
	General water quality parameters (field) <sup>i</sup>	Baseline	Weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a).
	General and detailed water quality parameters (laboratory) <sup>9</sup>	Baseline	Monthly	Quarterly/yearly	Water quality guidelines (e.g. IFC 2007a).

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Blasting	Ground vibration and airblast over-pressure	n/a	All blasts monitored	n/a	State/national/international guidelines (e.g. SA 1998).
	Noise, flyrock (distance travelled)	n/a	Selected blasts	n/a	State/national/international guidelines (e.g. IFC 2007b). No flyrock beyond safety exclusion zone.
	Erosion, subsidence, landslips, groundwater levels (see above)	n/a	Daily/weekly/event-based	Yearly/as required	Engineering design specifications; rehabilitation objectives.
<b>Underground mines</b>					
Dewatered material (cone of depression)	Mass/volume of material exposed to oxygen	Modelled predictions	Monthly	As required	Modelled data.
	Geochemical characterisation of lithologies <sup>h</sup>	Baseline/as required	As required	n/a	Geochemical condition not threatening rehabilitated landscape or downstream ecosystems.
	Hydrogeology (groundwater cone of depression)	Groundwater levels and flow rates (dewatering bores), adit flows	Baseline/monthly	Weekly	Quarterly/yearly
Blasting	General water quality parameters (field) <sup>i</sup>	Baseline/monthly	Weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a).
	General and detailed water quality parameters (laboratory) <sup>j</sup>	Baseline/monthly	Monthly	Quarterly/yearly	State/national/international guidelines (e.g. SA 1998).
	Ground vibration and airblast over-pressure (above ground)	n/a	All blasts monitored	n/a	State/national/international guidelines (e.g. IFC 2007b).
	Noise (above ground)	n/a	Selected blasts	n/a	State/national/international guidelines (e.g. IFC 2007b).

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Geotechnical stability	Wallrock stability, subsidence (above ground), landslips	n/a	Daily/weekly/event-based	As required	Engineering design specifications; rehabilitation objectives.
Underground air quality, fungus	See below—Occupational health and safety (OHS)	See below (OHS)	See below (OHS)	See below (OHS)	See below (OHS)
<b>Heap and dump leach piles</b>					
Ore material	Ore production rates, mass/volume of ore in leach pad	Modelled predictions	Daily	n/a	Modelled data.
	Geochemical characterisation of lithologies <sup>h</sup>	Baseline/as required	As required	n/a	Geochemical condition not threatening rehabilitated landscape or downstream ecosystems.
Hydrology (surface runoff and seepage)	Flow rates, water levels	n/a	Daily	Quarterly/yearly	n/a
Water quality (surface runoff and seepage)	General water quality parameters (field) <sup>f</sup>	n/a	Weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMICANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Monthly	Quarterly/yearly	
Hydrogeology (groundwater upgradient, beneath and downgradient of heap leach pad/ leach piles)	Groundwater levels	Baseline	Weekly	Quarterly/yearly	n/a
	Geophysical survey (e.g. time domain electromagnetic) to map sub-surface flow	As required	As required	As required	n/a
	General water quality parameters (field) <sup>f</sup>	Baseline	Weekly	Quarterly/yearly	State/national guidelines for groundwater quality. Baseline and upgradient.
	General and detailed water quality parameters (laboratory) <sup>g</sup>	Baseline	Monthly	Quarterly/yearly	
Geotechnical stability	Erosion, subsidence, landslips	n/a	Daily/weekly/event-based	As required	Engineering design specifications; rehabilitation objectives.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/ feasibility phase <sup>b</sup>	Construction/ operations phase	Closure/post-closure phase (e.g. 3+ years)	
<b>Haul roads, access roads, exploration roads, drill pads</b>					
Road runoff/surface seepage water quality	General water quality parameters (field) <sup>7</sup>	n/a	Event-based/ as required	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>9</sup>	n/a			
Ambient noise	Noise (e.g. A-weighted decibels)	Baseline	As required	n/a	State/national/ international guidelines (e.g. IFC 2007b).
Geotechnical stability	Erosion, subsidence, landslips	Daily/weekly/ event-based	Daily/weekly/ event-based	As required	Engineering design specifications; rehabilitation objectives.
Aquatic ecosystems- organism passage	Passage design and operation; organism passage and persistence upstream and downstream	Baseline (passage requirements of aquatic and riparian biota)	Yearly/event-based	Yearly/event-based	Minimal alteration of organism distributions. Organism passage rates unchanged.
<b>Quarries</b>					
Pit water quality	General water quality parameters (field) <sup>7</sup>	n/a	Weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>9</sup>	n/a	Monthly	Quarterly/yearly	
Blasting	Ground vibration, airblast over- pressure, flyrock (distance travelled)	n/a	All blasts monitored	n/a	State/national/ international guidelines (e.g. SA 1998).
	Noise (e.g. A-weighted decibels)	n/a	Selected blasts	n/a	State/national/ international guidelines (e.g. IFC 2007b).
Geotechnical stability	Geotechnical stability (erosion, subsidence, landslips)	n/a	Daily/ weekly/ event- based	As required	Engineering design specifications; rehabilitation objectives.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
<b>Power generating facilities</b>					
Stack/flue emissions	Airborne contaminants (e.g. sulfur dioxide, nitrogen oxide, PM <sub>10</sub> , carbon monoxide)	n/a	As required	n/a	State/national/international guidelines (e.g. IFC 2007b).
<b>Ore crushing and processing facilities</b>					
Process water; site runoff/bund water	General water quality parameters (field) <sup>f</sup>	n/a	Daily/weekly/event-based	n/a	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Weekly/event-based	n/a	
<b>Primary smelting facilities</b>					
Stack/flue emissions	Airborne contaminants (e.g. sulphur dioxide, nitrogen oxide, PM <sub>10</sub> , carbon monoxide)	n/a	As required	n/a	State/national/international guidelines (e.g. IFC 2007b).
<b>Water storages, sediment basins, etc.</b>					
Hydrology	Flow rates, water levels	n/a	Event-based/as required	Quarterly/yearly	n/a
Water quality	General water quality parameters (field) <sup>f</sup>	n/a	Event-based/as required	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>g</sup>	n/a	Event-based/as required	Quarterly/yearly	
Sedimentation	Bathymetry (visual; surveyed cross-sections/profiles; remote sensing; digital terrain modelling); water storage capacity/residence time; sediment composition	n/a	Event-based/as required	Quarterly/yearly	Engineering design specifications.
Geotechnical stability	Erosion, subsidence, landslips	n/a	Daily/weekly/event-based	Quarterly/yearly	Engineering design specifications; rehabilitation objectives.

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
Aquatic ecosystems—organism passage	Passage design and operation; organism passage and persistence upstream and downstream	Baseline (passage requirements of aquatic and riparian biota)	Yearly/event-based	Yearly/event-based	Minimal alteration of organism distributions. Organism passage rates unchanged.
<b>Constructed wetlands</b>					
Hydrology	Flow rates, water levels	n/a	Event-based/ as required	Quarterly/yearly	n/a
Water quality/odour (influent, effluent)	General water quality parameters (field) <sup>c</sup> , odour	n/a	Continuous/weekly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>9</sup>	n/a	Continuous/ monthly/ seasonal	Quarterly/yearly	Design specifications for water quality and contaminant loads.
Sedimentation	Bathymetry (visual; surveyed cross-sections/profiles; remote sensing; digital terrain modelling); water storage capacity/residence time; sediment composition	n/a	Event-based/ as required	Quarterly/yearly	Engineering design specifications.
Geotechnical stability	Geotechnical stability (erosion, subsidence, landslips)	n/a	Daily/weekly/ event-based	Yearly/as required	Engineering design specifications; rehabilitation objectives.
Wetland vegetation	Vegetation health and diversity	n/a	Monthly/seasonal	Quarterly/yearly	n/a
<b>Other water treatment facilities (e.g. drinking water, greywater, sewerage)</b>					
Water consumption/ wastewater generation	Flow rates, water levels	n/a	Daily/weekly	n/a	n/a
	General water quality parameters (field) <sup>c</sup> , odour	n/a	Daily/weekly	n/a	Water quality criteria (on site use) or drinking water quality guidelines (e.g. NHMRC 2004; WHO, 2004).
Water quality/odour (influent, effluent)	General and detailed water quality parameters (laboratory) <sup>9</sup>	n/a	Weekly/monthly	n/a	

(continued)

Element	Parameters	Indicative frequency <sup>a</sup>			Performance evaluation criteria
		Exploration/feasibility phase <sup>b</sup>	Construction/operations phase	Closure/post-closure phase (e.g. 3+ years)	
<b>Solid waste disposal facilities</b>					
Waste generation	Rate of solid waste generation, reuse, recycling and disposal, according to type	Weekly/monthly	Weekly	n/a	n/a
Hydrology (leachate/runoff)	Flow rates	Weekly/monthly	Weekly/monthly	Quarterly/yearly	n/a
Water quality/odour (leachate/runoff)	General water quality parameters (field) <sup>c</sup> , odour	Weekly/monthly	Weekly/monthly	Quarterly/yearly	Water quality criteria (on site use) or discharge water quality guidelines (e.g. IFC 2007a; ANZECC & ARMCANZ 2000).
	General and detailed water quality parameters (laboratory) <sup>9</sup>	Monthly/quarterly	Monthly/quarterly	Quarterly/yearly	
	Direct toxicity assessment (macroinvertebrates, fish, larger vertebrates); refer to biodiversity management handbook	Monthly/quarterly	Monthly/quarterly	As required	Trigger value as determined by ANZECC & ARMCANZ (2000) procedures.
Geotechnical stability	Geotechnical stability (erosion, subsidence, landslips)	n/a	Daily/weekly/event-based	Yearly/as required	Engineering design specifications; rehabilitation objectives.
Visual	Pests/scavengers/litter	Daily	Daily	Quarterly/yearly	n/a

a Monitoring frequency for some locations may need to be higher during the wet season (and high flow periods) and lower during the dry season (and low/no-flow periods). A higher frequency will also be required before/during off-site discharge (e.g. in the case of downstream surface water monitoring). A trend towards continuous monitoring of environmental parameters is emerging as new technologies are being developed to enable more cost-effective and remote monitoring; continuous monitoring facilitates the identification of acute impacts (e.g. pulse of contaminated water) as well as long-term trends. Certain projects may require a higher monitoring frequency during closure than post-closure; monitoring frequencies for closure/post-closure are combined here for simplification.

b Monitoring frequency during the exploration/feasibility phase may vary with the expected time before commencement of operations.

c Calibration of pan evaporation factors required to ensure water balance uses accurate evaporation data/assumptions.

(continued)



- d Calibration/rating curve for each stream gauging station to enable conversion of water level data to flow rates.
- e Estimation of fluvial sediment transport rates is facilitated by continuous hydrology monitoring data (see Hydrology).
- f General field parameters may include pH, temperature, electrical conductivity/salinity, turbidity, dissolved oxygen and redox potential. In some cases, more detailed parameters (e.g. particular metals or other contaminants of concern) need to be monitored at a similar frequency as general field parameters. This may involve on site laboratory analysis or the use of field test kits.
- g Relevant parameters may include total suspended solids, acidity/alkalinity, major ions and ligands, metals, nutrients, organic carbon, hydrocarbons, E. coli, total coliforms, other potential site-specific contaminants (e.g. cyanide species, radionuclides).
- h Geochemical characterisation typically involves a combination of static tests (e.g. acid-base accounting, geochemical composition, mineralogy) and kinetic tests (column leach tests, sulfide oxidation rate tests, in situ measurement of pore space oxygen concentration). Refer to *Managing acid and metalliferous drainage* handbook.
- i More general occupational health and safety (OHS) aspects are beyond the scope of this handbook; refer to IFC (2007b) for further guidance.

**References:**

- ANZECC & ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water quality*, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.
- NHMRC 2004, *National Water Quality Management Strategy: Australian drinking water guidelines*, National Health and Medical Research Council.
- IFC 2007a, *Environmental health and safety guidelines for mining*, International Finance Corporation.
- IFC 2007b, *Environmental, health, and safety general guidelines* (General EHS guidelines), International Finance Corporation.
- SA 1998, AS 21872-1998 *Explosives—storage, transport and use—part 2: use of explosives*, Standards Australia.
- WHO 2004, *Guidelines for drinking water quality*, 3rd edn, World Health Organization.

**Table A2: Typical social elements of a mining project's monitoring and performance evaluation program**

Element	Parameters	Indicative frequency				Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)		
Livelihood/ socioeconomics	Livelihood/socioeconomic surveys (employment, income, financial resources, living costs, living conditions), economic diversity opportunities (dependency), job creation activities	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	Employment (level of workforce participation in local community, unemployment rates), income, land and assets are maintained or improved relative to living costs; wellbeing is maintained or improved.	
Social	Community networks, cooperation and relationships, social and civic participation, local and regional community leadership, social norms, pace of change of vulnerable communities	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	New families in the region participating in community services, rise/fall of social programs.	
Health and nutrition	Health/nutrition surveys (general health, diet, exposure to hazardous materials, drinking water quality, drug use, air quality, access to sanitation and health services, incidence of prevalent illnesses and sexually transmitted infections)	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	State of health and nutrition is maintained or improved, increase in dysfunctional behaviours, increased vulnerability of sub-populations (elderly, women, youth).	
Human	Skills, knowledge, education, expertise, in-out migration	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	Portion of people remaining in community after high school, high school diplomacy rates, portion of operational workforce that have remained in the community for [timeframe], retention rates, vocational enrolment rates.	
Water use	Downstream water use surveys (e.g. drinking, fishing/aquaculture, irrigation/farming, livestock, washing, bathing, small-scale mining, hydropower, recreation, cultural significance etc.)	Baseline/yearly	Quarterly/yearly	Yearly	Natural resources are maintained or improved.	

(continued)

Element	Parameters	Indicative frequency			Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)	
Built	Physical infrastructure/investment; buildings, transportation, traffic movement on/off site, community facilities and communications	Baseline/yearly	Yearly; traffic movement ongoing	As negotiated, as part of closure plan	Utilisation of community amenity, housing availability, use of public transportation, impacts of traffic quantified and managed, volume of private (home) ownership.
Land use	Land and asset surveys; land use requirements and impacts; economic value of land, assets and natural resources; grazing animals and intensive agriculture/ horticulture (see Table A1)	Baseline	As required	Yearly	Natural resources are maintained or improved.
Archaeology and Indigenous cultural heritage/physical cultural resources (PCR)	Cultural heritage sites, grave sites, archaeological sites/artefacts, spiritual beliefs and practices	Baseline	As required	As negotiated, as part of closure plan	Culturally significant sites and artefacts are preserved.
Governance	Formal and informal leadership structures, political systems and protocols, capacity to respond to development	Baseline/yearly	As required	Yearly	Time taken for development approvals, voting turnout, local support for local/municipal government.
Non-Indigenous cultural heritage/practice	Heritage significance, rates of decay, stability, safety	As required	Yearly	Yearly	Conservation requirements of National Estate listing or state/territory heritage listings and/or heritage guidelines.
Indigenous cultural elements in rehabilitation	Bush tucker, habitat for key wildlife, biodiversity related to traditional diet	Baseline	Frequent in early stages; half yearly after initial rehabilitation; yearly thereafter	Yearly	Conservation and transplanting of key elements, protection of specific areas from disturbance followed by monitoring return of key species, consultant to assess community satisfaction.
Pre-existing historic underground workings and shafts	Safety controls, bat populations, tourism use/impacts, interpretive plans, progress toward implementation, economic measures of community value	Baseline	As required	As required	Conservation plans; safety risk assessment control measures.

(continued)

Element	Parameters	Indicative frequency			Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)	
Visual/aesthetics	Photography, aerial photography/ remote sensing	Baseline	Yearly	Yearly	n/a
Community grievances and attitudes	Social disturbances (e.g. noise, traffic) and complaints; community attitude towards the mining project	Baseline	Weekly/monthly	Quarterly/yearly	Continued community support for the project; community complaints and suggestions addressed.
Incidents	Traffic incidents; project-related injuries; downstream impacts associated with discharge events	As required	As required	As required	Rate of incidence declines.
Compensation	Number of people affected, nature and extent of disturbance to land/ assets/livelihood; measures taken to compensate for loss/disturbance	As required	As required	As required	Affected persons are appropriately compensated.
Water quality, hydrology, hydrogeology, air quality, noise, vibration/ airblast/ flyrock, flora and fauna	See Table A1	n/a	n/a	n/a	n/a
Livelihood/ socioeconomics	Livelihood/socioeconomic surveys (employment, income, financial resources, living costs, living conditions), economic diversity opportunities (dependency), job creation activities	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	Employment (level of workforce participation in local community, unemployment rates), income, land and assets are maintained or improved relative to living costs; wellbeing is maintained or improved.
Social	Community networks, cooperation and relationships, social and civic participation, local and regional community leadership, social norms, pace of change on vulnerable communities	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	New families in the region participating in community services, rise/fall of social programs.

(continued)

Element	Parameters	Indicative frequency			Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)	
Health and nutrition	Health/nutrition surveys (general health, diet, exposure to hazardous materials, drinking water quality, drug use, air quality, access to sanitation and health services, incidence of prevalent illnesses and sexually transmitted infections)	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	State of health and nutrition is maintained or improved, increased dysfunctional behaviours, increased vulnerability of sub-populations (elderly, women, youth).
Human	Skills, knowledge, education, expertise, in-out migration	Baseline/yearly	Quarterly/yearly	As negotiated, as part of closure plan	Portion of people remaining in community after high school, high school diplomacy rates, portion of operational workforce that have remained in the community for [timeframe], retention rates, vocational enrolment rates.
Water use	Downstream water use surveys (e.g. drinking, fishing/aquaculture, irrigation/farming, livestock, washing, bathing, small scale mining, hydropower, recreation, cultural significance, etc.)	Baseline; Yearly	Quarterly/yearly	Yearly	Natural resources are maintained or improved.
Built	Physical infrastructure/investment; buildings, transportation, community facilities and communications	Baseline/yearly	Yearly	As negotiated, as part of closure plan	Utilisation of community amenity, housing availability, use of public transportation, volume of private (home) ownership.
Land use	Land and asset surveys; land use requirements and impacts; economic value of land, assets and natural resources; grazing animals and intensive agriculture/ horticulture (see Table A1)	Baseline	As required	Yearly	Natural resources are maintained or improved.
Archaeology and Indigenous cultural heritage/physical cultural resources (PCR)	Cultural heritage sites, grave sites, archaeological sites/artefacts, spiritual beliefs and practices	Baseline	As required	As negotiated, as part of closure plan	Culturally significant sites and artefacts are preserved.

(continued)

Element	Parameters	Indicative frequency			Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)	
Governance	Formal and informal leadership structures, political systems and protocols, capacity to respond to development	Baseline/yearly	As required	Yearly	Time taken for development approvals, voting turnout, local support for local/municipal government.
Non-Indigenous cultural heritage/practice	Heritage significance, rates of decay, stability, safety	As required	Yearly	Yearly	Conservation requirements of National Estate listing or state/territory heritage listings and/or heritage guidelines.
Indigenous cultural elements in rehabilitation	Bush tucker, habitat for key wildlife, biodiversity related to traditional diet	Baseline	Frequent in early stages; six monthly after initial rehabilitation; annually thereafter	Annually	Conservation and transplanting of key elements, protection of specific areas from disturbance followed by monitoring return of key species, consultant to assess community satisfaction.
Pre-existing historic underground workings and shafts	Safety controls, bat populations, tourism use/impacts, interpretive plans, progress toward implementation, economic measures of community value	Baseline	As required	As required	Conservation plans, safety risk assessment control measures.
Visual/aesthetics	Photography, aerial photography/remote sensing	Baseline	Yearly	Yearly	n/a
Community grievances and attitudes	Social disturbances (e.g. noise, traffic) and complaints; community attitude towards the mining project	Baseline	Weekly/monthly	Quarterly/yearly	Continued community support for the project; community complaints and suggestions addressed.
Incidents	Traffic incidents; project-related injuries; downstream impacts associated with discharge events	As required	As required	As required	Rate of incidence declines.
Compensation	Number of people affected, nature and extent of disturbance to land/assets/livelihood; measures taken to compensate for loss/disturbance	As required	As required	As required	Affected persons are appropriately compensated.

(continued)

Element	Parameters	Indicative frequency			Performance evaluation criteria
		Exploration/ feasibility phase <sup>a</sup>	Construction/ operations phase	Closure/post- closure phase (e.g. 3+ years)	
Water quality, hydrology, hydrogeology, air quality (including dust), noise, vibration/airblast/ flyrock, flora and fauna	See Table A1	n/a	n/a	n/a	n/a

a Monitoring frequency during the exploration/feasibility phase may vary with the expected time before commencement of operations.



## Appendix 3

### Grievance management mechanism

A recent study on mining and community grievances, which draws on mining industry practitioner experience of conflict in operational settings, has identified the elements of grievance mechanism management that have worked, and those that have not worked (see Kemp, D & Bond, C 2009, *Mining industry perspectives on handling community grievances*, Centre for Social Responsibility in Mining in collaboration with Harvard Kennedy School's Corporate Social Responsibility Initiative).

A summary of these elements is provided below, with several additional elements added for completeness.

What works:

- an organisational culture that supports a focus on community perspectives
- a dedicated pipeline for complaints and grievances
- an effective documentation procedure to record, track and close out resolved grievances
- a grievance mechanism established in the context of a broad-based engagement process that aims to establish trusting relationships
- a grievance mechanism that allows/encourages grievances to be lodged in local languages or dialects
- collaborating with local people and others about how best to handle grievances, before they escalate
- taking a principled approach, including, at a minimum: transparency, accessibility, timeliness, fairness and a simple/reliable recourse mechanism
- considering the surrounding context, not issues in isolation
- understanding the problem, not just solving the issue
- building social competencies of community relations practitioners as well as senior leaders
- a community relations function with structural power and formally recognised authority
- ensuring community relations personnel handling grievances are from the local community.
- What does not work:
  - failure to plan for conflict because of an assumption that it can be avoided, or that it can be handled 'on the fly'
  - giving communities no way to lodge issues, so they must resort to destructive behaviour to get a response from the company
  - reliance on negotiation and position bargaining, rather than also including dialogue to build mutual understanding

- ignoring or refusing to engage 'least trusted' groups on grievance-handling processes
- a disconnected and isolated community relations function
- a lack of documented grievance procedures and grievance record keeping
- incumbent leadership that will not accept legacy issues as part of their own management responsibilities
- limited prior knowledge through lack of analysis and due diligence
- words without action
- third parties who impose processes ill-suited to the local context
- corporate procedures not modified or adapted to local cultures and conditions.