

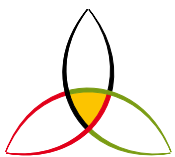


Australian Government

# A GUIDE TO LEADING PRACTICE SUSTAINABLE DEVELOPMENT IN MINING



LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY



SOCIAL  
ECONOMIC  
ENVIRONMENTAL

LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY

## A GUIDE TO LEADING PRACTICE SUSTAINABLE DEVELOPMENT IN MINING



JULY 2011

# FOREWORD

The *Leading Practice Sustainable Development Program for the Mining Industry* series of handbooks has been produced to share Australia's world-leading experience and expertise in mine management and planning. The handbooks provide practical guidance on environmental, economic and social aspects through all phases of mineral extraction, from exploration to mine construction, operation and closure.

Australia is a world leader in mining, and our national expertise has been used to ensure that these handbooks provide contemporary and useful guidance on leading practice.

Australia's Department of Industry, Innovation and Science has provided technical management and coordination for the handbooks in cooperation with private industry and state government partners. Australia's overseas aid program, managed by the Department of Foreign Affairs and Trade, has co-funded the updating of the handbooks in recognition of the central role of the mining sector in driving economic growth and reducing poverty.

Mining is a global industry, and Australian companies are active investors and explorers in nearly all mining provinces around the world. The Australian Government recognises that a better mining industry means more growth, jobs, investment and trade, and that these benefits should flow through to higher living standards for all.

A strong commitment to leading practice in sustainable development is critical for mining excellence. Applying leading practice enables companies to deliver enduring value, maintain their reputation for quality in a competitive investment climate, and ensure the strong support of host communities and governments. Understanding leading practice is also essential to manage risks and ensure that the mining industry delivers its full potential.

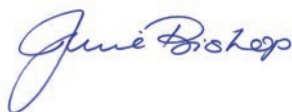
These handbooks are designed to provide mine operators, communities and regulators with essential information. They contain case studies to assist all sectors of the mining industry, within and beyond the requirements set by legislation.

We recommend these *leading practice* handbooks to you and hope that you will find them of practical use.



**Senator the Hon Matt Canavan**

Minister for Resources and Northern  
Australia



**The Hon Julie Bishop MP**

Minister for Foreign Affairs

### **Disclaimer**

This publication has been developed by the Australian Centre for Sustainable Mining Practices with the support of the Leading Practice Sustainable Development Program for the Mining Industry Steering Committee. The effort of all contributors is gratefully acknowledged.

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Users of this handbook should bear in mind that it is intended as a general reference and is not intended to replace the need for professional advice relevant to the particular circumstances of individual users. Reference to companies or products in this handbook should not be taken as Commonwealth Government endorsement of those companies or their products.

Cover image: *Morwell River after diversion*

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# 1.0 INTRODUCTION

## The Purpose and Layout of this Guide



Figure 1.1 - Progressive rehabilitation of the box cut (background) during portal construction at Newcrest's Kencana mine, Indonesia.

The Leading Practice Sustainable Development Program in Mining initiative was a collaborative effort launched in 2006 by the Australian government and the mining industry. The handbooks built on the then state-of-the-art knowledge and case studies contained in the original Best Practice Environmental Management in Mining (BP) series of booklets launched in 1995. Although in some areas the content is dated, the BP series still provides excellent supplementary and background reading to the Leading Practice series.

The Leading Practice Program aimed to identify the key issues affecting sustainable development in the mining industry and provide information and case studies to enable a more sustainable basis for its operations. The output of the Program was a series of handbooks relevant to all stages of a mine's life—exploration, feasibility, design, construction, operation, closure and rehabilitation as illustrated in Figure 1.2.

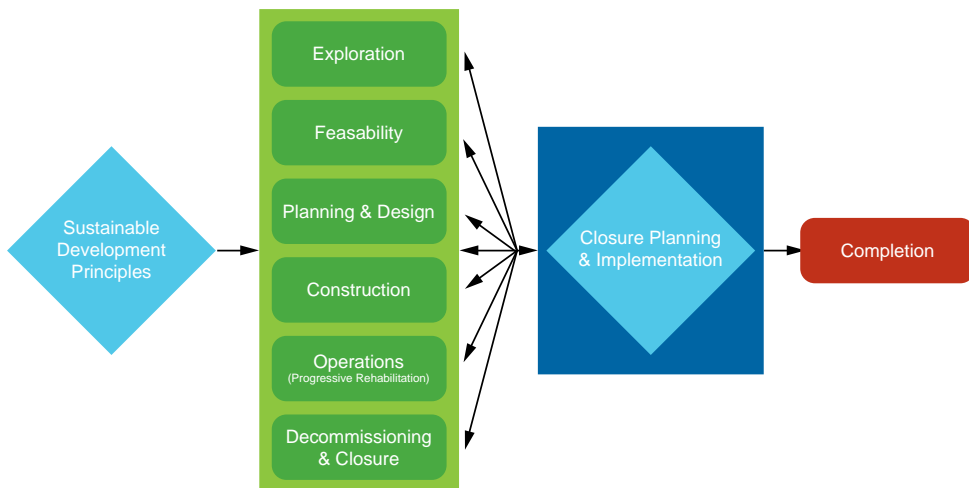


Figure 1.2: The phases of a mining project covered by the Leading Practice Handbooks.

There are 14 handbooks in the Program plus an Overview. The titles of the handbooks are (in alphabetical order):

- Airborne Contaminants, Noise and Vibration
- Biodiversity Management
- Community Engagement and Development
- Cyanide Management
- Evaluating Performance: Monitoring and Auditing
- Hazardous Materials Management
- Managing Acid and Metalliferous Drainage
- Mine Closure and Completion
- Mine Rehabilitation
- Risk Management
- Stewardship
- Tailings Management
- Water Management
- Working with Indigenous Communities

**Airborne Contaminants, Noise and Vibration** (referred to in the text as LP ACNV)

This handbook addresses issues related to emissions of particulates (dust, diesel and silica), noise and vibration and how they are controlled at mining operations. These issues can have a significant impact on local communities and contribute to concerns about ongoing environment and health risks.

**Biodiversity Management** (LP Biodiversity)

This handbook addresses the broad issue of biodiversity management for mining operations, including environment protection and conservation legislation, flora and fauna and environmental offsets. Mining often occurs in or near sensitive natural environments, so biodiversity protection needs to be a key part of the operation's environmental management program.

**Community Engagement and Development** (LP Community)

This handbook addresses some of the key issues around these processes in the minerals sector, offering insights, approaches and practical discussion about the challenges that companies may encounter as they engage with local communities and seek to contribute to their short and long-term development. The handbook is supported by case studies that illustrate how these challenges have been addressed in particular contexts.

**Cyanide Management** (LP Cyanide)

Managing cyanide to minimise risks to human health and environmental health represents one of the key challenges facing the mining industry. This handbook addresses principles and procedures for effective and safe cyanide management. The handbook takes a risk management approach and is closely based upon the leading practice principles contained in the International Cyanide Management Code (the Code).

**Evaluating Performance: Monitoring and Auditing** (LP Monitoring)

This handbook addresses the ongoing impact of all stages of a resource project from initial planning through development and operation, to closure and rehabilitation. It includes requirements for an environmental impact assessment for a project, development and implementation of environmental management systems, performance, monitoring and auditing, all of which contribute to the company's social licence to operate.

**Hazardous Materials Management** (LP Hazardous)

This handbook outlines the principles to manage hazardous materials in the mining industry. A hazardous material can be defined as 'any material (biological, chemical, physical) which has the potential to cause harm to humans, animals, or the environment when it is improperly handled, used, treated, stored, disposed of or otherwise managed'. Any point in the lifecycle or supply chain can include a hazardous material.

### **Managing Acid and Metalliferous Drainage (LP AMD)**

This handbook addresses management issues related to the environmental impacts and remediation of acid and metalliferous drainage in the mining industry. The problem of acid and metalliferous drainage encompasses all issues associated with the actual and potential environmental effects of sulfide oxidation resulting from mining activities. Its significant potential for long term environmental degradation makes it one of the biggest environmental issues facing segments of the mining industry.

### **Mine Closure and Completion (LP Closure)**

Poorly closed and derelict (orphaned and abandoned) mines provide a difficult legacy issue for governments, communities, companies and ultimately tarnish the mining industry as a whole. Increasingly, as access to resources becomes tied to industry and corporate reputation, effective closure processes and satisfactory mine completion becomes critical to a company's ability to develop new projects. Poor planning and inadequate financing invariably increase the costs of closure and decrease overall profitability, hampering a company's ability to develop new projects. Taking a more integrated approach to mine closure planning, and doing it earlier, can achieve effective mine closure and completion.

### **Mine Rehabilitation (LP Rehabilitation)**

This handbook outlines the principles and practices of mine rehabilitation. Rehabilitation is the process used to mitigate the impacts of mining on the environment. The long-term objectives of rehabilitation can vary from simply converting an area to a safe and stable condition, to restoring the pre-mining conditions as closely as possible to support the future sustainability of the site.

### **Risk Management (LP Risk)**

Risk is an unavoidable consequence of mining operations and there is a business case to embrace a robust and comprehensive risk management approach. This handbook addresses issues related to identifying, assessing and managing risk in the mining industry.

### **Stewardship (LP Stewardship)**

Stewardship involves the care and management of a commodity through its life cycle. Stewardship needs to be an integrated program of actions aimed at ensuring that all materials, processes, goods and services are managed throughout the life cycle in a socially and environmentally responsible manner.

### **Tailings Management (LP Tailings)**

This handbook addresses tailings management through the life of the project (including planning, design, operation and closure of tailings storage facilities). Tailings are a combination of the fine grained solid material remaining after the recoverable metals and minerals have been extracted from mixed ore and any process water remaining. The physical and chemical composition varies with the nature of the material that is the inherent geophysical and geochemical parameters, and the manner of its processing ie the mechanical and/or chemical transformation process and any activities. Tailings may be stored in a variety of ways, depending on their geochemical properties, the site topography, climatic conditions and the socio-economic context in which the mine and mill operations are located.

### **Water Management** (LP Water)

This handbook addresses sustainable priorities within the mining sector for water management. Water is integral to virtually all mining activities and typically the prime medium that can carry pollutant into the wider environment. It can also be a major source of community concern relating to its usage, particularly in areas with established reliance on agricultural or other water intensive industries. Consequently, sound water management is fundamental for all mining operations. Water must be managed at all stages of the life cycle of minerals operations. A key principle to sound water management is the recognition of water as an asset with social, cultural, environmental, and economic value.

### **Working with Indigenous Communities** (LP Indigenous)

This handbook acknowledges the traditional and historical connection that Aboriginal people have to the land, and the effects of colonisation and development, including mining. It will also address cross cultural issues and how mine operations impact on neighbouring Indigenous communities. Issues to do with the recognition of land rights and native title are discussed as well as how relationships are developed and fostered between mining companies and Indigenous communities through agreement making. Recognition of differences in culture, language, law and custom are an important part of these processes, and some principles of community engagement are discussed.

This reference guide consolidates the information in the handbooks into a single reference guide, organised in such a way to reflect the life cycle of a mining operation. Reflecting their importance in highlighting the key messages, selected case studies have been retained. The handbooks have proven to be extremely popular internationally and therefore in this reference book, a number of international case studies have been used to emphasise the global applicability of the key messages. These case studies were not in the LP handbooks.

Chapter 1 provides the background and context and attempts to define the concept of sustainable development and mining. Chapters 2 to 5 reflect the life cycle of a mining operation, commencing with pre-development (mineral exploration and feasibility), development (construction and infrastructure), operations (mining and processing) and post-development (rehabilitation and closure). The Chapters are in turn arranged in the key areas of sustainable development reflected by the 14 themes listed above.

The structure is designed to enable a reader to quickly access a key area of sustainability throughout the life cycle of a mine. For example a mine manager may be interested in leading practices in water course diversion during the development phase of a mine. The key points and a case study highlighting the points are provided in Chapter 3, development and construction, water management.

Although this guide was primarily the work of a single author, there were numerous contributors to it, principally through their work in the original Handbook compilation. Individual contributors are listed at the end of this guide. It is stressed that this guide is a consolidation of the Handbooks and where relevant, selected sections are re-emphasised in this publication.

## The Target Audience

### **Mine management**

This book is primarily intended for use as a management tool to improve sustainability outcomes on mine sites. The target audience for this reference text play a variety of roles in and around the industry although the primary focus is onsite mine management—the pivotal level for implementing leading practice at mining operations. It is the responsibility of the mine manager and his/her team to assess risk, identify opportunities and take action to enhance the value of the operation. Managers are also in a position to use this experience to formulate a business case to change the practices of a company at a corporate level. Implementing sustainable mining practices will add value to a mining operation and enhance the lifestyle amenity of the community in which it operates.

The term mine management however is used generically here and also captures those with management responsibilities in functional areas such as exploration, construction, maintenance, metallurgy, mining as well as environmental and community liaison. The layout of this guide will allow these individuals to extract information of most value to them in their day to day or strategic roles.

### **Technically-oriented audience**

In addition, people with an interest in leading practice in the mining industry will find this handbook relevant, including mining company directors, managers, community relations practitioners, environmental officers, mining consultants, suppliers to the mining industry, and government regulators.

### **Non-technical audience**

The book will also serve as a useful textbook on the fundamentals of sustainable mining practices for those who may not worked in or been exposed to the industry. Although some sections are necessarily technical, the book has been written to be understood by a wide range of readers. Reflecting the broad nature of stakeholders associated with or potentially impacted by mining operations, the reference guide has also been written for representatives from non government organisations (NGOs), mining communities, neighbouring communities, and students. It has been written to encourage those people to play a critical role in continuously improving the mining industry's sustainable development performance.

Figure 1.3 illustrates the target audience for the water management handbook. This figure, like many of the figures, graphs and photographs in this book have been sourced directly from the Handbooks. The original sources of the graphics can be found in the handbooks. It can be seen from the diagram that corporate management would be most interested in those areas that will affect the strategic direction of the business including drivers for leading practice. Site-based management will naturally focus on monitoring performance and key system risks. Operational staff need good quality, detailed technical guidance to better implement leading practice “on the ground”. They are most in touch in with the technical and community requirements.

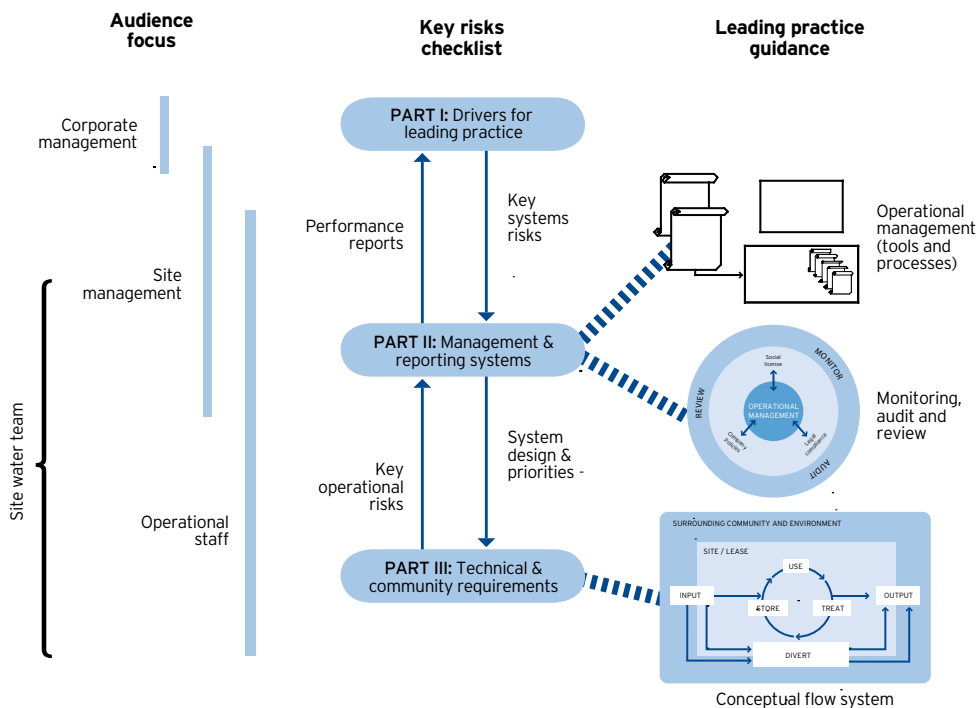


Figure 1.3 - The key features of leading practice around which a typical handbook is organised, including the focus audiences and their primary areas of interest (source: LP Water)

### International audience

Despite their focus on the Australian mining industry, the Leading Practice handbooks have been well received internationally. They have been translated into a number of languages including Spanish, Chinese and Indonesian. This reference guide is designed to have more of a global audience and a number of new case studies, highlighting international leading practice, have been included.

Given the wide target audience for the reference book and the wide variation in mining experience of the reader, a comprehensive glossary is provided at the end of the Book.

## Sustainable Development and the Mining Industry

The most widely accepted definition of sustainable development is provided in the World Commission of Environment and Development in its landmark report *Our Common Future* (the Brundtland Report) – ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’. There have been attempts to restate and expand this definition, often with relevance to particular sectors or populations, and some of these will be explored later in the handbook. 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).



In the minerals sector, sustainable development means that investments in minerals projects should be financially profitable, technically appropriate, environmentally sound and socially responsible. Businesses involved in extracting non-renewable resources have come under mounting pressure to embed the concept of sustainability into strategic decision-making processes and operations. In addition to these considerations, responsible corporations have been able to move towards sustainability by developing a range of appropriate stewardship initiatives. Economic development, environmental impact and social responsibilities must be well managed, and productive relationships must exist between governments, industry and stakeholders. Achieving such a situation is simply a 'good way to do business'.

It should not be presumed that a given operation needs to achieve leading practice in every aspect of its activities since to do this may demand allocation and mobilisation of resources (such as people and money) in excess of the benefit to be gained. Potentially this could detract effort from management of other areas of leading practice.

Recently, a range of sustainable development policy frameworks have been developed by industry and other organisations that are now acting as drivers for improved practice. One such approach is that of the International Council on Mining and Metals (ICMM) which adopted a set of 10 Sustainable Development Principles in 2003 to harness the industry's commitment to sustainable development within a strategic framework (ICMM, 2003). To give practical and operational effect to the ICMM commitments, the Minerals Council of Australia (MCA) developed Enduring Value - the Australian Minerals Industry Framework for Sustainable Development (MCA, 2004). Enduring Value is designed to assist minerals sector managers to implement the sector's commitment in a practical and operational manner that is targeted at the site level.

In adopting Enduring Value, the Australian minerals sector is recognising that its future is linked to the pursuit of sustainable development, which means operating in a manner that is "attuned to community expectations and which acknowledges that business has a shared responsibility with government, and with broader society, to help to facilitate the development of strong and sustainable communities" (MCA, 2004).

## Sustainable Mining

There is no one definition of sustainability that has been universally adopted by the mining industry. Some useful descriptions include the following:

- miners can achieve sustainable development by embracing the social, environment and economic pillars - James 1999.
- offsetting or reinvesting the benefits from the depleting mineral asset - Labonne 1999.
- the simultaneous pursuit of sustained or enhanced: environmental quality, economic growth, and social justice - Eggert 2006.

Hilson and Basu (2003, p. 320) discuss further the difficulties of applying sustainable development to a mining context. The reasons cited include the existence of innumerable frameworks and indicator sets and a multitude of interpretations of sustainable development. The authors propose a framework of sustainable development based on the three pillars underpinned by good governance (p. 329). The issue of governance implies good government, which includes a sound fiscal and regulatory environment as well as good corporate governance. It becomes a particularly important issue when companies work off shore, especially in countries where corruption is widespread.

**MINING COMMUNITY:** Broken Hill

**LOCATION:** Broken Hill, Australia

**BRIEF DESCRIPTION:** Open pit and underground base metals

**AREA OF LEADING PRACTICE:** Sustainable mining practices - safe; environmental leading practices; economic development; community engagement; resource utilisation

**HANDBOOK(S) REFERENCE:** Various

**DESCRIPTION OF INNOVATION:**

The famous Broken Hill silver, lead and zinc ore body is still being exploited 110 years after its initial production. Clearly, a world class mineral resource with high metal grades is a major reason for its longevity. The mines along the famous "line of lode" were, without deliberately trying, implementing sustainable development practices. They included (and still include) a focus on:

- Economic development. Although the mine was located in a relatively isolated part of Australia (1200km west of Sydney), staff were constantly reminded that mining is a globally competitive business. Furthermore, mines are price takers not price makers and management could only control the cost-side of the business. Being in the lowest quartile of the cost curve should enable the company to sustain itself if and when the lead or zinc price dropped. Higher cost producers would have to close. Furthermore the mines were the catalyst of the creation of numerous businesses servicing the mines.
- Community support and engagement. The Zinc Mine as it was known was the lifeblood (along with the North mine) of the city. Examples of its strong corporate citizenship included:
  - providing an amenities scheme whereby employees took out loans from the company to purchase white goods, and other furnishings for a home.
  - providing low interest home loans.
  - providing a kindergarten and employing teachers.
  - maintaining two cricket ovals, a bowling green and a recreational park for its workers and their families.
  - supporting a local university and supporting the arts and the local repertory society.
- High standards of safety. The company was a global leader in safety innovations and being one of the first to employ safety officers. It was one of the first to insist on the wearing of personal protective equipment in the form of safety glasses and hearing protection. Penalties for breaking the rules were severe with a week's suspension from work for a miner if he was guilty of a blasting infringement for example.

- Mining the resource efficiently. The mine utilised six different underground mining methods some of which were truly innovative, such as the Vertical Crater Retreat and Undercut and Fill methods. The emphasis was on extracting as close to 100% of the ore body as possible, as the metal grades were exceptionally high.
- High environmental standards. The community surrounded the mining operation and thus it was in its interests to protect the environment. It was one of the first in Australia to have its own nursery for tube stock for mine rehabilitation. It also provided free plants to employees. One of its employees, (Albert Morris), in the 1930s, created a green belt surrounding the mines, to repair the damage caused by timber getting for mining and smelting and also to repair the effects of over-grazing by sheep.

The sum total of these initiatives was a mining field with exceptional longevity, staffed by a loyal, committed workforce living in a city with amazing amenities considering its isolation, with a very stable population base.



Figure 1.4 - Vista of North Broken Hill mine



Figure 1.5 - Stable but unvegetated dumps in South Broken Hill

### **Sustainable Mining Practices - An Holistic Model**

A body of literature exists suggesting that mining can contribute to sustainable development by focusing on successful economic, environmental and community outcomes. However, in a mining context, these pillars (the triple bottom-line) fail to adequately account for two important areas, essential for a sustainable mining operation, as illustrated by the Broken Hill example. One “missing” dimension is safety, which receives more attention in the mining sector than arguably any other industry. The media coverage and political focus applied to any mine “accident” exceeds virtually all other industries. It is not unusual for regulators to force a mine to close on the basis of a poor mine safety record. Recent examples include the San José mine in Chile and the Pike River mine in New Zealand. Older examples include the Westray mine in Nova Scotia, the Lassing mine in Austria, the Beaconsfield, Gretley and the Moura mines in Australia and the Sago Mine in West Virginia. Although acknowledged as extremely important by regulators and mining companies, its importance is not borne out in the literature on mining and sustainable development.

The second missing dimension is a focus on extraction practices of the mineral resource itself. In the literature, researchers have tended to concentrate on the exhaustibility of the resource as a depleting asset (Auty and Mikesell, 1998). However, the researchers approach the subject from a macro level and usually from an economic perspective. It is suggested that there is a need to focus on the micro level, at the individual mine site, where the resource is managed sustainably or unsustainably. This element or dimension can be termed ‘resource efficiency’ or simply ‘efficiency’. It differentiates mining from other industries and is the basis or platform for any sustainable benefit to flow to the community. In most countries, the mineral resource is “owned” by the State on behalf of the community; therefore, there is an immediate link to the triple bottom-line.

Too often, an ore body or coal seam is mined without any regard for the long term, resulting in a reduced mine life. In addition, government regulators rarely scrutinise how companies mine a particular deposit, usually focusing only on the safety and environmental aspects. The reasons may be political, given that the community has more of an interest in these aspects, or simply the lack of technical expertise in government.

Mine managers will be on track in establishing a sustainable mining operation if they then focus on the following five areas: safety, environment, economy, efficiency and the community (see Figure 1.6). A brief description of each dimension follows.



Figure 1.6 - Sustainable Mining Practices (Laurence 2011)

### **Safety**

For both ethical and business reasons, a mining operation should aim to prioritise safety. Characteristics of safe mines include a commitment to risk management; appropriate attitudes and behaviours; reporting systems need to be in place; a focus on education and training; and a focus on processes and equipment (Laurence 2005).

### **Economy**

Unless a mine is profitable, it cannot be sustainable. The aim for mine managers is to generate profit responsibly for as long as possible by keeping costs to a minimum while maximizing revenue. This will also maximize the equitable benefits to all stakeholders, including shareholders, employees, local communities and businesses, which depend on the mine, as well as the governments that benefit by means of taxes and royalties.

### **Resource Efficiency**

A mine also has to be efficient in the way the resource is managed and extracted. Mining engineers, geologists and metallurgists collaborate to optimize resource extraction. Examples of non-sustainable mining practices abound and include “high grading” the ore body, which entails mining only the highest grade material for short term gain. This is a practice used by companies and individuals within those companies with a short time frame. This, in turn, is a symptom of the high turnover at many mine sites and the drive to “make one’s name” as quickly as possible without regard for the longer-term extraction of the deposit. Particularly in these times of high commodity prices, it makes sense to consider mining lower grades which will extend the mine life and thus stakeholder benefits, without compromising the revenue stream. Another example is underground mining only the lowest horizon

of a thick coal seam (>6 metres), rather than mining the full seam thickness. Mines in China have been criticised for their safety record but due to the implementation of novel techniques such as longwall top coal caving, it is possible to extract the full height of even a 10 metre seam, thus optimising the extraction of this valuable resource. Efficiency also encompasses the management dimension at a mine site, as poor management decisions can often lead to production difficulties or equipment breakdown or industrial relations or other factors that impact on optimum resource extraction.

### **Environment**

Adopting leading environmental management practices on mine sites makes excellent business sense. Unless steps are taken in the planning and operational stages to protect environmental values, long-term liabilities such as acid mine drainage, may result. Thanks in part to the increasing awareness of environmental issues, there is considerable literature relating to the environment and sustainable development. The potential for environmental disasters such as those that occurred at Baia Mare, Los Fraillos, Omai, OK Tedi and many more are ever present however.

### **Community**

Finally, a mine needs a 'social licence to operate'. Unless the community is engaged and supportive of a mining operation, opposition and confrontation may ensue. Mining operations run by corporations have been disrupted on many occasions in the recent past particularly from local artisanal and small-scale miners, who were mining in many cases before the commencement of the larger-scale operations. A current example of the difficulties faced by mining companies is the Masbate operation in the Philippines where small-scale miners regularly tunnel beneath open pit benches. Blasting or operating machinery on these benches can be extremely hazardous for both company personnel and the small scale miners.

Dysfunctional community interaction will ultimately distract management from its main focus of efficiently running the mine. Enlightened mining companies, particularly those operating in the developing world, maintain their social licence to operate by undertaking various initiatives, including preferentially employing local people; training and providing skills in businesses or enterprises that will endure after the mine closes and so on. An example is the Sepon gold-copper operation in Laos, employing approximately 7000. Most of the employees are drawn from the 70 villages surrounding the mine. The company has built extensive training workshops to provide electrical, mechanical, welding, automotive and other skills through apprenticeship and other programs. It also provided the funding for enterprises such as silk weaving and farming innovations.

**LOCATION:** Vilabouly District, Savannakhet Province, Laos

**BRIEF DESCRIPTION:** Sepon open pit gold and copper mine

**AREA OF LEADING PRACTICE:** Community Engagement

**HANDBOOK(S) REFERENCE:** Community Engagement

**DESCRIPTION OF INNOVATION:**

A range of community and government engagement processes implemented at the Sepon Project in Laos (Lao Peoples Democratic Republic [PDR]) since commencement has ensured that effective communication channels were in place to enable continuous change in the project scope. These changes included the mining of copper as well as gold, the ongoing expansions of both copper and gold resources, the addition of a second tailing storage facility and the construction of a large permanent accommodation camp. These mechanisms have enabled an initially small mining company the ability to continuously explore and develop while maintaining the social licence in a remote country with no previous history of engagement with multinational mining companies.

**Background**

Minerals and Metals Group (MMG) and the Government of Lao PDR (GoL) own 90 per cent and 10 per cent respectively of Lane Xang Minerals Limited (LXML). LXML has been operating the Sepon Project in Vilabouly District of Savannakhet, Lao PDR, since initial gold mining approval was granted by the Lao PDR Government in 2002. The Sepon Project currently consists of the open pit mining and processing of oxide gold ore; the mining and processing of various types of copper ore and the mining of limestone to support copper processing.

**Government and Community Engagement**

A Steering Committee was established by GoL and the Sepon Project team in 2002 to oversee the construction and operations of the Sepon Project. The committee continues to meet regularly (3-4 times per year) both at site and in the capital city of Vientiane, and is attended by representatives of all the Ministries and Government Departments who are responsible for the various aspects of the project. The Sepon Project representatives provide updates on financial, technical, environmental and community aspects of the operation. Questions are raised by both parties and often vigorous debate ensues.

Similarly, a committee consisting of local village and government leaders was established during initial project construction. This committee usually meets monthly and is attended by senior representatives from all directly affected villages and the Sepon Project, including the site General Manager. Matters which are of concern to both the local community and the project are discussed and resolved, these include managing in-migration, ongoing access to land and controlling theft.



### **Impact Assessment Engagement**

Prior to the development of each project expansion or change, an Environmental and Social Impact Assessment (ESIA) is conducted. A critical component of these ESIA's is engagement with directly affected villages that will experience impacts on their land and/or water resources as a result of the expansion. This has involved meetings in each village with interpreters who are skilled in local languages. In addition, separate women's meetings are held to ensure women's concerns and ideas are also included in the assessment and agreed mitigation strategies.

### **Special Purpose Engagement**

A range of special purpose engagement processes have also been established to enable implementation of agreed mitigation and management strategies. An example is the ongoing cultural heritage work involving archaeological surveys which is guided by a Memorandum of Understanding between LXML, GoL and an International University. This has resulted in the excavation, recording and preservation of artefacts of international significance.



Figure 1.7 - Site Based Stakeholder Engagement, Sepon Operations

\*Case study provided by Geraldine Maguire

## Leading Practice

The handbooks in the Leading Practice Sustainable Development in Mining series integrate environmental, economic and social aspects through all phases of mineral production from exploration through construction, operation and mine-site closure. The concept of leading practice is simply the best possible way of conducting activities for a given site. As new challenges emerge and new solutions are developed, or better solutions are devised for existing issues, it is important that leading practice be flexible and innovative in developing solutions that match site-specific requirements. Although there are underpinning principles, leading practice is as much about approach and attitude as it is about a fixed set of practices or a particular technology.

Leading practice sustainable development management is an evolving discipline. As new problems emerge and new solutions are developed, or better solutions are devised for existing problems, it is important that leading practice be flexible in developing solutions that meet site-specific requirements. While recognising that companies must consistently, as a minimum meet legislative requirements, it also expects them to go beyond the minimum. Leading practice is an evolving target—it is adaptive to changing standards and situations that are frequently encountered in major mining operations.

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 holistically, ensuring positive financial, social, safety, efficiency and environmental outcomes for all stakeholders. A long-term timeframe is considered so that potential adverse outcomes are managed in both the short and long terms. Consideration of long-term outcomes is particularly challenging as the predictive data sets may be incomplete, a number of variables may modify the outcomes, and actual outcomes may not be fully understood or predicted. Nevertheless, leading practice demands that a best estimate of future impact is periodically reassessed and reasonable steps are taken to implement financially, socially and environmentally appropriate outcomes. The level of precision of such estimates also needs to be communicated.

A key feature is the measurement of variables and performance outcomes to identify potential modifications to the processes for the mutual benefit of all stakeholders. Leading practice includes a program to monitor inputs, processes and outputs. This information is incorporated in one or a number of managements systems. This may be incorporated in existing management systems such as safety management systems, environment systems and quality systems.

Leading practice includes being able to identify and manage competent technologists and communicators and ensure that they participate in programs to maintain their competence. A peer review process is important to ensure leading practice evolves with changing technology and social expectations and standards.

Leading practice organisations are now incorporating social considerations into all aspects of their performance evaluation. This takes two forms: 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 strong 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 sites, local, regional, national and even international aspects.

## The Case Studies

This reference guide is primarily designed to be used by practitioners. Feedback from those using the handbooks (SKM 2008) indicates that the case studies in particular provided invaluable guidance. In total, there were over 110 case studies used in the handbooks and a selection of these were chosen to be included in this reference text on the basis of their:

- relevance to practitioners on mine sites.
- balance between metals, coal and industrial minerals.
- outcomes.

The case studies used are integrated in summary form into the text to highlight the particular point being made. Reference is made to the location of each case study in a particular handbook (eg LP Name of Handbook). These examples are supplemented by new, mainly international case studies as illustrated by the Sepon mine above.

The publishers acknowledge the contribution of the original collectors of the case studies and thank them and the companies involved for allowing the material to be used for educational purposes. Indeed, this reference guide would not have been possible without the efforts of all those who contributed to the leading practice handbooks.

## 2.0 PRE-DEVELOPMENT: MINERAL EXPLORATION AND FEASIBILITY



Figure 2.1 – Exploration drilling can produce significant sustainability impacts  
(photo - Roberts - DMR - [http://www.mining.unsw.edu.au/kcmi/Govern/NSW\\_DMR\\_2.pdf](http://www.mining.unsw.edu.au/kcmi/Govern/NSW_DMR_2.pdf))

### Key Messages

- a focus on community engagement and support during this stage will pay dividends for any future operation
- if the community engagement process is flawed, the approval to mine process will be delayed or threatened
- cross-cultural skills are essential in the early phases of a potential mining project
- mine planning and design needs to integrate social, environmental as well as economic considerations
- mine closure planning needs to begin in the early stages
- the earlier the life of mine planning begins, the fewer the problems later
- EIA and SIA studies should be completed in parallel with prefeasibility and later feasibility studies

- effectively applying risk management principles early lays the foundation for good relationships throughout the whole mine life cycle
- baseline studies need to be undertaken for
  - biodiversity
  - noise, air quality
  - water
- the potential for acid drainage needs to be assessed as early as possible and mitigation strategies planned.

## Introduction

This Chapter introduces Leading Practice (LP) as a tool that, if used at the very beginning of the mining cycle, will set the scene for success in implementing LP throughout the subsequent development, operational and closure cycles. Topics covered include the mineral exploration and the feasibility study phases.

Mineral exploration covers the initial phases of a prospective mine's life. At this stage of the mining cycle, there are no guarantees that a mine will eventuate. In fact, mineral exploration rarely results in the development of a mine. However, in most cases, there will be environmental and social impacts that will need to be addressed including access tracks, drill pads, disposal of wastes, and community concerns and expectations.

Mineral exploration and evaluation techniques range from the most environmentally benign, such as remote sensing from satellites, to the more invasive, such as close spaced intensive drilling. Environmental planning and management offer their greatest benefit when preventing, or at least minimising, environmental impacts by:

- promoting environmental awareness within exploration companies;
- educating and training employees and contractors; and
- developing and applying industry codes of practice (Environment Australia 1995).

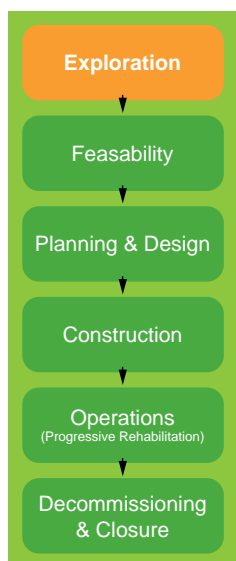
Exploration activities have the potential to adversely impact on the environment if they are not managed appropriately. Aspects that require management include:

- Clearing of vegetation and other types of disturbance to fauna.
- Soil erosion and stream sedimentation.
- Spreading of weeds.
- Noise, light and dust level.
- Disturbance to culturally significant sites.
- Disruption to other land users, such as farmers and the local community.
- Contamination of soil and water and.
- Injury to, or detrimental effects on the health and wellbeing of employees, other persons at work and the public.

The application of high standard environmental management practices in exploration is essential to ensure that such activities are properly controlled with the protection of environmentally sensitive areas and community concerns effectively addressed. A number of guidelines are available to assist mining exploration company personnel to achieve leading practice (see for example AMEC 2010).

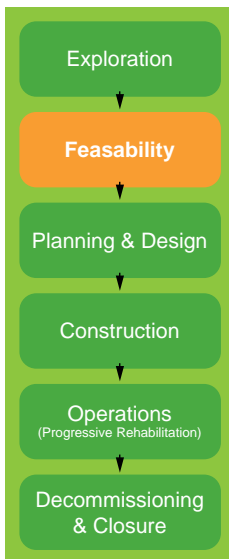
### Key Management Tasks in the Exploration Stage

Key activities that need to be undertaken at this early stage and which will be useful for future planning and closure include:



- developing a community engagement plan, comprising
  - community and stakeholder identification and analysis
  - socio-economic baseline study and social impact assessment
  - engagement with the local community— residents may advise how places or objects of cultural significance should be protected (refer to LP **Community** for further details).
- preliminary discussions with community and stakeholders on the mine concept and collation of issues that need to be addressed in future environmental impact assessments (EIAs) or source impact assessments (SIAs).
- collecting early environmental baseline data including surface and ground water quality and quantity, soil types, vegetation types, meteorological data.
- preliminary assessment for waste rock characterisation including testing of sulphide ore bodies for acid-based accounting and metals.
- development of relationships with local stakeholders, regulators and community.
- preliminary assessment of current land use and ownership.

## Key Management Tasks in the Feasibility Stage

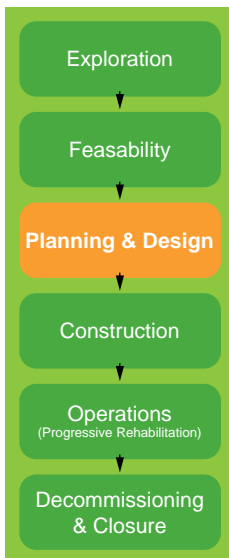


Once a mineral resource has been identified, it is then necessary to conduct a project evaluation to determine whether the resource can be commercially mined.

Feasibility is an integral element of the mine evaluation process and can be defined as an assessment of the economic, environmental and social impacts of the potential mining project. The objective is to clarify the basic factors that govern project success and, conversely, identify the major risks to project success. An attempt is made to quantify as many variables as possible in order to arrive at a potential value. The implications of mine closure need to be considered accurately at this stage.

Feasibility studies are required in the pre-production stages to justify the continued investment of money in the project and usually consist of a scoping study, a pre-feasibility study and final or bankable feasibility study. At this stage, the project should commission an EIA and an SIA which will provide valuable information on the baseline conditions.

## Key Management Tasks in the Planning & Design Stage



The goal of mine planning and design is to achieve an integrated mine systems design, whereby a mineral is extracted and prepared at a desired market specification and at a minimum unit cost within acceptable environmental, social, legal and regulatory constraints. It is a multidisciplinary activity.

Mining engineers and mine geologists generally have the most influence in mine planning and design. They need to understand and take into account the mine closure issues, and integrate economic, environmental and social elements into the decision-making process. For example, they will need to be informed about the preliminary community expectations for post-mining land uses, the environmental quality and the aesthetics of the area. These expectations can impact, for example, on the location of access roads and waste storage facilities.

## The Business Case for Sustainability in Mineral Exploration and Feasibility

The conduct of an operator in the pre-development (exploration/feasibility) stage is critical to maximising future shareholder value. If the operator cannot establish and maintain the trust of the community and government, the potential value of a resource is unlikely to be realised. The application of leading practice and sustainable development principles is key to demonstrating competency and building trust. Getting this wrong may lead to:

- limited access to the resource (less potential profit) .
- delays in approvals (greater costs).
- refused approvals.

## Airborne Contaminants, Noise and Vibration

### Introduction

A range of airborne contaminant, noise and vibration issues are associated with mineral exploration activities as illustrated in Figure 2.1. The transient and often isolated nature of exploration creates an environment for potential clashes with local residents, unless operations are carefully monitored and considerable effort is made to keep the community informed of activities. At this stage of development, there is usually a limited amount of activity that will generate significant emissions. Nevertheless, any drilling, excavation and material handling and transport activity that could potentially impact on neighbours should be conducted with that impact in mind. It may require the location or timing of various activities to be managed so that they have minimal impacts, or watering of dusty operations that are close to sensitive areas.

As design detail progresses, there may be a need to refine emission control specifications based on improved inputs for modelling. Hence, it is important that the engagement with air quality consultants continues as required. Baseline monitoring, if any, will be in progress through this stage.

The following case study provides an example of how exploration activities operated in a densely populated area of Victoria. For many years a company has struggled to fully drill out its exploration leases due to the noise restrictions involved with operating machinery in a built up urban area. The company had experimented with many forms of noise suppression including, surrounding rigs with shipping containers, large hay bales, erecting sound walls and even digging large pits for the drilling rigs to work in. These measures all had some degree of success but were far from ideal. In 2007 the company purchased an Atlas Copco CS14 drill rig with the intention of enclosing the unit within a fully noise attenuated containers.

The drilling department identified the need to make the system modular and self-contained. Six sea containers were utilized; four on the ground floor and two for the mast of the rig encapsulate the entire worksite. Everything from drilling fluids, tools, drill rods, power generation and even the crib room are enclosed within the system.



After consulting with acoustic engineers the decision was made to use a mixture of noise attenuation products on the walls of the containers to reduce noise both internally and externally. The noise attenuation products included sound deadening paint, 50mm sound absorbent foam and a 6mm nylon sound barrier.

The combination proved to be extremely successful, reducing noise emissions from 110dB at the machine to a measured 52dB immediately outside the containers and 38dB measured at 200m. With a 30dB reduction inside the containers the noise attenuation was celebrated as a great win in terms of operator comfort and safety. The containerised rig has now successfully completed six months of 24hr drilling at two sites both sites are within 200m of residents. To date no complaints from the surrounding neighbours have been received (see LP **ACNV** p.75).

### **Planning / Environmental Assessment Phase**

Good planning is essential to mitigate noise impacts which might otherwise affect the surrounding community or the natural environment. Optimising the design and layout of a mine from the very earliest phase, or the way in which an exploration program is conducted, with the assistance of an acoustic specialist can minimise impacts and assist in meeting community expectations.

The first step in implementing leading practice for a new project or redevelopment of an existing project is to ensure you have appropriate expertise on your team. The team will conduct an environmental assessment that examines the proposal in detail and identifies all the potential sources of noise. The stages of work in the planning phase can be broadly categorised as follows:

- Background or Ambient noise monitoring within a potentially affected community.
- Setting noise criteria / design goals for assessing adverse impacts including on site and off site noise. The criteria vary slightly from State to State so are not covered in detail; refer to the EPA in each state.
- Predict noise levels for a number of future scenarios including on site and off site (transportation). This typically involves a comprehensive computer noise model.
- Where the assessment shows that the noise criteria will be exceeded, there is a requirement for feasible and reasonable mitigation measures to be incorporated which will enable impacts to be effectively reduced. Where this is not possible it is likely that acquisition of properties will be necessary.

### **Background or Ambient Noise Monitoring**

As part of the environmental assessment process for any project there is normally a requirement to understand and measure the existing ambient noise environment. Monitoring normally takes the form of unattended measurements using an automatic noise logger. The monitoring should be conducted over a sufficient time period to reflect the true and repeated conditions typically experienced in the area which are not unduly influenced by seasonal variations due to temperature inversions, winds, insects etc. In practice, continuous monitoring is conducted for a minimum of one week period at representative surrounding residences or other noise sensitive receivers (e.g. schools or churches) ideally prior to the mine being operational or while the mine is not operating.

The information obtained from these measurements is normally used to set criteria for the project. Of most importance is the background noise level (technically the LA90), which is normally measured in 15 minute periods.

Meteorological conditions can significantly influence noise levels. Steady wind, for instance, generally causes an increase in background noise levels due to wind in trees. Strong winds and rain can lead to falsely inflated noise levels. To enable periods of adverse weather to be identified, a weather station should be set up to continuously monitor wind speed and direction and rainfall. Noise data should then be filtered for periods of weather conditions that had an influence over the recorded noise results.

Some residences surrounding new mine sites already experience noise from road traffic, rail lines, other existing mines, or other intrusive noise. In these situations, in addition to unattended monitoring there may also be a need to do attended noise monitoring to understand the existing noise levels and estimate the contribution from each of these sources. These measurements may also provide a way of validating the noise prediction methodology to be used in assessing noise from the project. Often measurements may be done at one or two representative properties in order to validate any predictions.



Figure 2.2 - Example of environmental noise logger in operation.

### **Community liaison to avoid noise and air complaints**

Liaison between mining companies and the community is important at every point, from the beginning of the proposal stage, throughout the investigative, assessment and approval processes, and throughout the mine's operation. The community

must be kept informed and involved in the decision-making process affecting them if a good working relationship is to develop between all involved parties. A good working relationship is the keystone to a win/win approach involving mining and the community.

Implementation of an effective community consultation program will gain public confidence and lead to a smoother planning and approval phase and a more efficient operational period. Lack of knowledge and understanding frequently lead to the fears in the community surrounding a mining proposal. The misconceptions which can then arise commonly result in objections and difficulties which serve no constructive purpose and promote a spirit of non-cooperation.

By providing information and a contact point at the onset of a mining project, and continuing to respond to community concerns, mining companies are in a better position to implement a successful environmental management program.

As part of a Noise and Vibration Management Plan, a mining company must develop a policy for community liaison in dealing with noise and vibration issues. The management plan should establish the protocol for handling complaints which will ensure that the issues are addressed and that appropriate corrective action is identified and implemented if and where necessary. This protocol should be proactive and responsive, and, as a minimum, involve the following (including identifying the people responsible for the various actions):

- Identify contact persons at all potentially affected properties, and give them a project outline (together with details of the procedures for lodging complaints and the expectations they may have about the response mechanisms that will be implemented).
- Forward all complaints to the person responsible for handling them.
- Keep records regarding the source and nature of the complaint.
- Investigate the complaint to determine whether a criterion exceedance has occurred or whether noise and/or vibration have occurred unnecessarily.
- If excessive or unnecessary noise and/or vibration have been caused, corrective action should be planned and implemented.
- Corrective action should be planned and implemented if excessive or unnecessary noise and/or vibration has been caused.
- Report details of complaints and corrective action should be reported.
- Inform complainants that their complaints are being addressed, and (if appropriate) that corrective action is being taken.
- Carry out follow-up monitoring or other investigations to confirm the effectiveness of the corrective action.
- Inform complainants the successful implementation of the corrective action that has been taken to mitigate the adverse effects.

Some assessment procedures are deemed significant enough to warrant a public inquiry, to ensure that all issues are suitably aired and decisions on approval and

conditions are appropriate. In NSW, for example, some projects are subject to public hearings by expert panels that make technical comment and recommendations for government consideration in the final decision. An example is the process that was invoked for the assessment of the Anvil Hill (now **Mangoola**) coal mine project in the Hunter Valley. A key aspect of this process was the way in which decisions about private property acquisition were made in the light of uncertainties about the accuracy of model predictions of air and noise impacts in the surrounding community.

To compensate for noise impacts, and given the very low background noise conditions of the locality, noise conditions be placed on the project are significantly more stringent than the standard approach to noise management. These included requirements on the proponent to:

- undertake (with landowners consent) architectural noise treatments at all residences where operational noise levels meet or exceed a noise criterion of 35dB(A).
- undertake (with landowners consent) architectural noise treatments at all residences where traffic and rail noise levels exceed the relevant road and rail noise criteria.
- purchase (with landowners consent) any private property that experiences operational noise levels at or above 40dB(A), and
- establish and implement a comprehensive noise monitoring program, which includes real-time monitoring of noise impacts with the view to modifying mining operations as appropriate to reduce noise impacts.

Approval condition 27 for the project requires an Air Quality Monitoring Program that includes a combination of real-time monitors, high volume samplers and dust deposition gauges to monitor the dust emissions of the project, and an air quality monitoring protocol for evaluating compliance with the air quality impact assessment and land acquisition criteria in the approval. Condition 26 requires the operator to regularly assess real-time air quality monitoring and meteorological monitoring and to relocate, modify or stop mining operations as required to ensure compliance with the air quality criteria (see LP **ACNV** p.26).

## Biodiversity Management

### Key biodiversity threats and opportunities

Many countries including Australia possess native biodiversity that is world class. There are in Australia more unique mammal, invertebrate and flowering plant species than 98 percent of other countries. Discoveries such as the living fossil, the Wollemi Pine near Sydney highlight the botanical richness of the continent. As this is the case for many regions, mining companies often have to take this into account. New Caledonia is one such case as it hosts the world's richest nickel laterite deposits, and rich variety in biodiversity.

**MINE:** Tiébaghi

**LOCATION:** Koumac, Province Nord, New Caledonia

**BRIEF DESCRIPTION:** Open pit (nickel).

**AREA OF LEADING PRACTICE:** EIA

**HANDBOOK(S) REFERENCE:** Biodiversity Management

#### **DESCRIPTION OF INNOVATION:**

Nickel mining has taken place in New Caledonia for over 100 years. The environmental legacy of un-rehabilitated mines is significant in the form of erosion and scarring of the massifs which are highly visible throughout the islands.

This project by Societe Le Nickel (SLN) involved estimating the ecological values within the environmental impact study of the DOME project on the Tiébaghi massif in New Caledonia. The objectives included having a better understanding of the ecology of the site to evaluate the impacts of mining on the natural environment in order to be able to choose the proper rehabilitation project and to define the right compensatory measures.

Three stages are involved:

**Stage 1:** Synthesis of known data producing a map of sensible zones or items (e.g. outstanding vegetation, number of endangered species birds life, snake or lizard life, zones without electrical ants, fresh water index)

**Stage 2:** notation of ecological zones on the basis of 3 criteria

- criteria 1: vegetation formation
- criteria 2: conservation state
- criteria 3: endangered or outstanding species

**Stage 3:** computation of the ecological value for each zone (based on outstanding vegetation formation) Each criteria provides an index between 0 and 1: the global index which is the mean value of the 3.

Such richness also brings challenges. A key impediment for managing biodiversity is the limited taxonomic coverage to date, with estimates that only one in four species in Australia is known (PMSEIC 2005). For the minerals industry this represents significant uncertainty in pre-mining biodiversity assessment particularly in biodiverse regions.

There is a growing recognition of the critical role that business can play (in partnership with governments, the community and researchers) to change the threats to biodiversity into opportunities. Through these strategic partnerships impacts that have taken place over the last 200 years due to increasing land clearing, unsustainable land management practices, introduced species and fragmentation of the landscape can be understood, minimised and, where possible, reversed. As one of the major business groups in Australia, the mining industry has taken the opportunity to use its size in playing a leading role in biodiversity conservation.

In recent decades, despite increasing community interest in biodiversity, there is often a lack of long-term commitment of resources required for effective biodiversity research and management in Australia. The mining industry is taking up this opportunity to significantly assist biodiversity conservation and recovery through the following mechanisms:

- support of researchers, industry groups and consultants undertaking biodiversity studies (for example, on values, impact assessment and management of threats, and maximising return of values on disturbed areas).
- enhancing human resources, skills and knowledge in areas that could assist in these complex matters.
- developing partnerships with communities, conservation groups and other organisations to address this issue.
- encouraging young graduates in biodiversity investigation and research through traineeships, graduate studies and partnerships.
- developing, maintaining and sharing databases with government and researchers for biodiversity data (for example, Western Australia's Alcoa Frogwatch program, and the sharing of data that took place as part of the Western Australia Regional Forest Agreement process).
- sharing through publishing key research findings, for example the jointly Government and mining industry funded Pilbara Bibliographic Database.
- maintaining the balance between field biologists/scientists and those responsible for management of land, water and biodiversity values.
- leading through the development of best practice research and processes.

Mitigation and offsets are being increasingly considered by Australian regulators and mining companies. Mitigation generally refers to actions taken to avoid, reduce or compensate for the effects of (direct or indirect) environmental damage. Offsets refer to actions aimed at compensating for unavoidable damage. When applied, these concepts can effectively balance access to mineral resources with protection of biodiversity values. Further development of these approaches is likely to provide increasing opportunities for the mining industry, as it seeks to adopt sustainable biodiversity management practices.

Prior to undertaking any operations, mining companies need to delineate the biodiversity values in a particular area. This is influenced by a range of social and economic factors, and the resulting information is essential for the identification of key risks to biodiversity, and the effective design of management programs, rehabilitation and closure objectives.

Baseline monitoring involves studying some element of biodiversity that is not expected to change without being disturbed. In determining what baseline monitoring is required, it is critical to understand the range of influential factors within a specific environment. Surveys and monitoring programs should differentiate between the direct and indirect impacts of the exploration and mining operations, and any other factors that may threaten local and regional biodiversity values.

The initial phases of baseline monitoring involve reviewing background information available on biodiversity values within the local, regional, national and international context. Some state government agencies have published a series of guidance statements for baseline biodiversity studies in different bioregions (for example, the Environmental Protection Agency 2004a,b). This helps ensure minimum standards of assessment, and promotes the integration of localised baseline surveys into a broader regional context.

The practice of establishing protected areas or those set aside for special or restricted use is used throughout the world to ensure long-term conservation of biodiversity values. Current legislation excludes mining from areas that possess particularly high conservation and biodiversity values. In such cases, mining and certain other land and water uses are deemed incompatible with the environment's long-term sustainability.

The decision to close mineral sand mining on sensitive parts of Australia's east coast in the 1980s is one example. Despite the existence of known, viable mineral deposits, society, through government legislation, has decided that other land uses, such as National Parks, take precedence over mining. Another example, also involving sand, is provided in the Shelburne Bay case study. Mining leases have been granted over areas later shown to be of significant conservation and biodiversity value, and whose sustainable conservation may be incompatible with proposed mining operations. 'No go' areas should be identified at the first stage of any project, and certainly prior to any disturbance. In the first instance, leading practice pre-mining biodiversity surveys, and effective impact assessment and mine planning procedures may raise environmental concerns. After discussion with government and other stakeholders in the area, a decision may be taken not to proceed with mining operations in that area. Proactive government and community efforts are sometimes required to secure protection for those areas where values are not identified by a company during surveying or planning, or where information comes to light as a result of research undertaken independently of the mining company. Government involvement, as in the case of **Shelburne Bay**, may require special legislation to protect biodiversity and conservation values.

The dunefields of Shelburne Bay had been placed under mining lease for silica sand mining. The mining proposal would have involved the removal of two dune systems, Conical and Saddle Hills, near Round Point, Shelburne Bay, as well as the construction of a major port facility from the eastern end of Shelburne Bay via Rodney Island to deep water offshore.

Proposals to mine the area in the 1980s were overruled by the Commonwealth Government on the basis of the conservation value however the dunefields remained technically available for mining operations. In 2003 the leases came up for renewal, but due to the concerns from Aboriginal groups, conservationists and members of the scientific community, the Queensland Government decided to cancel the leases when applications were made for their renewal. The Government passed special amendments to the (Queensland) Mineral Resources Act 1989 to confirm that the right of renewal of the leases was being revoked thereby ensuring the environmental and conservation values of the area are protected.



Figure 2.3 - Shelburne Bay's silica sand

Industry, governmental and non-governmental organisations have sought to create guidelines on no-go zones for mining both nationally within countries, and globally through international conventions and agreements. International mining companies that are members of the ICMM, and Australian members of MCA, have agreed not to mine in existing World Heritage Areas. Dialogue continues to further the consensus on measures necessary to maintain the values of other protected areas.

In Australia, any development project is subject to national and state assessment if values of significance have been defined under the relevant legislation. There are



protected areas under both Federal and State legislation that may exclude mining and/or exploration activities in particular areas (for example national parks or marine parks).

Surveys by mining companies and others may occasionally reveal exceptionally high biodiversity values in areas that do not currently have legal protection. Detailed assessment of these values and the potential impacts of mining may indicate that the exclusion of mining activity is warranted.

### **Assessing impacts to enable minimisation, mitigation and rehabilitation**

Environmental and social impact assessment (ESIA) should be an iterative process of assessing impacts, considering alternatives, and comparing predicted impacts to the established baseline. At a minimum, the following assessments should be made in and around the proposed project area:

- an assessment of the impact level, (ecosystem, species and/or genetic).
- an assessment of the nature of the impact (primary, secondary, long term, short term, cumulative).
- an assessment of whether the impact is positive, negative or has no effect.
- an assessment of the magnitude of the impact in relation to species/habitat richness, population sizes, habitat sizes, sensitivity of the ecosystem, and/or recurrent natural disturbances.

Many existing mining projects have conducted an ESIA some time ago, or in some cases, not at all. For these projects, it is important that biodiversity assessment and management considerations are built into their EMS and any other relevant internal and regulatory systems and procedures. It is also important that these assessments are periodically reviewed to ensure they are consistent with any changes in circumstances, such as new flora discoveries.

When assessing biodiversity impacts, it should be recognised that the intensity of impacts varies over the life of a project. Typically low at the start, the intensity of the impact increases markedly through the construction and operation phases and diminishes as planned closure occurs. The following case study illustrates one example of how one Australian mining company helped preserve the habitat of the Glossy Black Cockatoo, which is listed as 'threatened' under the Queensland Nature Conservation (Wildlife) Regulation, 1994 (see LP **Biodiversity** p.21). C. lathami is a large bird with a highly specialised diet. On Queensland's North Stradbroke Island, it has only been recorded feeding on two to three species of Allocasuarina trees, and is therefore very dependent on this food source. The trees were common in disturbed lands, and are now one of the more abundant tree species in developing rehabilitation following heavy mineral sands mining. The outcomes of the project have:

- provided the company with information to manage this species within its lease areas.
- expanded the knowledge base by contributing to a much larger study of the species within the south east Queensland region, thereby helping to secure its future.
- identified potential beneficial effects and opportunities for planting suitable food tree species for rehabilitation of mined land.

## Community Engagement in the Early Stages

### Introduction

It is often before or during exploration activities that a company's community engagement begins. In some cases, negotiations and the consent of land owners or Indigenous groups will be necessary. Like first impressions, the quality of community engagement at this early stage is very important as it will influence future relationships.

From a future operations aspect, it is essential that the exploration company focuses on the community engagement side. The greater the effort in this early part of the mining cycle, the more the rewards further into the cycle, such as credibility with the community, leading to acceptance of the company sincerity of concern for community welfare. Conversely, there are numerous cases where the exploration company has not followed appropriate protocols or has upset the local community, leading to the cessation of exploration and jeopardising any future mining on the affected land.

Community engagement and development are overlapping but distinct processes. Effective community engagement is an integral part of community development, but engagement can also be undertaken for other purposes; for example, to address community concerns about environmental impacts. Community development likewise involves more than just interacting with the community; for example, designing programs and linking with government and other organisations.

Table 1 provides illustrative examples of the types of activities that can be broadly categorised in terms of these two processes during mineral exploration. The examples span a wide variety of engagement and development activities, from information provision through to empowerment. They are provided to give an indication of the sorts of activities individual operations may choose to undertake—they are by no means prescriptive, as the activities listed will not be appropriate for every operation.

**Table 1: Community engagement and community development activities during exploration (source: LP Community)**

<b>Project stage</b>	<b>Examples of community engagement activities</b>	<b>Examples of community development activities</b>
Exploration	<p>Discussions and dialogue for the purposes of:</p> <ul style="list-style-type: none"> <li>• seeking permissions for access to land</li> <li>• negotiating land use and other agreements</li> <li>• identifying and addressing cultural heritage issues</li> <li>• informing people of exploration activities and timetables.</li> </ul> <p>Managing expectations and addressing community concerns about:</p> <ul style="list-style-type: none"> <li>• the impacts of exploration</li> <li>• potential for future development</li> <li>• opportunities for the community if the resource is developed.</li> </ul>	<p>Facilitating opportunities for local people to find employment with, or provide products or services to exploration undertakings.</p> <p>Assisting Traditional Owner groups to build their capacity to negotiate.</p> <p>Supporting or contributing to infrastructure development in areas where exploration is occurring.</p>

The following case study from the LP handbook series illustrates how good engagement in the exploration phase of a project provided the good will and trust to allow one of Australia's largest longwall coal mining operations to co-exist with one of its finest wine-growing areas. In the mid-1990s **Xstrata's Bulga Coal** mine, operating in the Hunter Valley, New South Wales applied for exploration licences to investigate further coal resources in an area beneath 40 commercial vineyards and adjacent to Wollombi Brook, a significant second-order stream in the area. In a public meeting attended by 200 local residents, strong concerns were expressed about the impacts of underground mining on viticulture and the area's water resources, which were reported in state-wide press (LP **Community** p.15).

In response, the company formed a specific project team and established a community consultation committee to address the community's concerns. Agreement was reached with the community on the construction of a simulated vineyard over the existing South Bulga underground mine, to assess the impacts of subsidence on the vineyard infrastructure. The community was kept informed of the results of both the exploration program and the viticulture trials through field days and newsletters. During the development of the environmental impact statement (EIS) for the continuation of South Bulga's underground workings to the new Beltana highwall, longwall punch mine, a more detailed impact assessment was carried out for each property to be undermined. Private property management strategies were developed and tailored to each property and provided to owners in their own booklets. Following project approval, the booklets were further enhanced as a part of the subsidence management plan process. Finally, a comprehensive consultation program was established for the ongoing management of Beltana Mine.

These initiatives strengthened the relationship between the mine and the community and aided in minimising the environmental impacts of mining on the vineyards. A testament to the success of the consultation programs was that only two community objections were received on the development application and the supporting EIS.



Figure 2.4 - Vineyard monitoring program at Beltana

### **Baseline studies and social impact assessments (SIA)**

Large development projects in Australia are generally required to conduct an SIA as part of the environmental approvals process. Traditionally, this was the only time when the issue of social impacts was given formal consideration. However, leading companies in the industry are now voluntarily undertaking the equivalent of SIAs at their existing operations to develop a better understanding of local communities and to manage significant events such as expansions and closures. A variety of terminology is used to describe these exercises—such as social monitoring, social assessments or socio-economic baseline studies—but the common element is the focus on identifying and tracking the social impacts of a project, both positive and negative, and the key community issues associated with the project.

A comprehensive SIA should aim to:

- identify the key social, environmental, demographic and economic factors that constrain or drive change in the particular community or region.
- understand how the establishment, expansion or closure of a mining operation will impact on the community or region.
- define key baselines against which to measure past and future changes, and whether or not these relate specifically to the impact of the mining operation.
- identify potential risks and opportunities to the community or region from the presence of the business and indicate how these might be avoided or secured.
- look to identify existing programs, services, projects and/or processes (such as a community or regional plan) with which an operation could integrate potential initiatives.

There are a variety of methods and approaches to conducting baseline studies and social impact assessments. Researchers may use different frameworks, based in methodologies derived from a range of social sciences, including economics, sociology, anthropology, social geography, community development, rights-based frameworks, communication, public affairs or social psychology. Company or site representatives commissioning the SIA/socio-economic baseline study and writing the scope should understand that there are many different approaches available.

Assessments should utilise both qualitative data (from interviews and focus groups) and available quantitative data (on demographic trends, labour market and employment data, income distribution, education levels and health indices).

In obtaining community input, it is important to be as broad and inclusive as possible to ensure that all relevant issues have been identified. In particular, operations need to avoid only engaging with groups and individuals who are positive or have high influence. It is just as important to involve marginalised groups who may not necessarily come forward voluntarily, plus the 'silent majority', whose perspective is sometimes overlooked due to vocal community groups or individuals. As previously emphasised, women are also important stakeholders within communities and workplaces and may bring different perspectives and views on issues from men.

The engagement processes that are used need to take account of the circumstances and communication needs of particular circumstances. Sessions may have to be held after hours, in different locations, and different styles of presentation and communication will often be necessary. Consideration of literacy levels and working cross-culturally with communities for whom English is not the primary language may also be important.

The following case study from British Columbia in Canada presents the results of a study of 15 communities associated with mining and impacted by declining socio-economic conditions.

**MINING COMMUNITY:** Tumbler Ridge

**LOCATION:** British Columbia, Canada

**BRIEF DESCRIPTION:** Open pit metallurgical coal mining region

**AREA OF LEADING PRACTICE:** Socio-economic and health conditions in mining communities; Knowledge Translation; Integrated Mine Planning

**HANDBOOK(S) REFERENCE:** Community Engagement

**DESCRIPTION OF INNOVATION:**

In 2005, a collaborative research study (funded by the Canadian Institutes of Health Research and supported by the Mining Association of British Columbia) between the Department of Mining Engineering and the School of Population and Public Health at the University of British Columbia was initiated. The purpose of the study, known as “The Mining and Community Health Project”, was to characterize socio-economic and health conditions of 15 communities associated with mines over a long period of time marked by declining economic conditions. One objective of accomplishing this research was to identify key community health and sustainability indicators that would serve to accommodate the actual needs of communities during mine planning.

Specifically, this investigation focused on: quantitatively examining the community level indicators describing economic, sustainability and demographic characteristics of 15 mining communities in the western Canadian province of British Columbia (BC) during a period of time during (1991 to 2001) when the mining sector experienced a downturn; and to assess the relationship between exposure to declining economic conditions and key health indicators (cardiovascular disease and mental health outcomes) over the same time period. Findings revealed that these mining communities were highly economically dependant on the mining sector, lacked economic diversity and women lacked equal employment and income opportunities. Over the study period, these mining communities also experienced population loss, and the communities that experienced mine closure lost more than 50% of their population. Periods of economic decline were also met with clinical and statistical significant increases in acute cardiovascular disease and mental disorders, and these health outcomes were exacerbated during mine closure.

Upon completion of the study, researchers were awarded additional funds from the Canadian Institutes of Health Research to share research findings with various stakeholders; within the population health field this process is known as Knowledge Translation (KT). Study indicators identified the Northern BC coal mining community of Tumbler Ridge to be particularly vulnerable to mining impacts. As such, researchers developed a KT plan to share research findings with municipal, health service, and mining representatives from this community. Overall objectives of the KT strategy included highlighting the importance of community health to the regional mining industry with aims of enhancing integrated community planning towards sustainable mining. A diverse array of KT strategies were undertaken and included: the development of a research summary report that highlighted main study findings in non-technical language; the presentation of research findings at a regional coal mining conference; and the facilitation of a Mining and Community Health workshop that brought together for the first time the municipality, health service providers, and the local mining industry to discuss research findings, evaluate the research summary report, and to discuss the development of a community sustainability plan. As a result, the research summary report has been widely distributed and is available on-line<sup>1</sup>. Interactions between researchers and stakeholders have also sparked interest in developing ongoing collaborative relationships to further apply the research evidence. In addition, the importance of the research findings and recommendations has garnered initial interest from stakeholders associated with another, newly approved BC mine project.



Figure 2.5 - Community at Tumbler Ridge

\*contributed by J.A. Shandro Department of Mining Engineering, The University of British Columbia, Canada; M. Scoble Department of Mining Engineering, The University of British Columbia, Canada; M. Koehoorn School of Population and Public Health, The University of British Columbia, Canada.

1 The Mining and Community Health research summary report was prepared by Shandro, Koehoorn, Scoble, and Hurrell in 2009. Mining and Community Health workshop participants were asked to evaluate a draft of the summary report to ensure clarity of research findings and applicability and relevance of associated recommendations. The final report is now available online at: <http://www.spph.ubc.ca/sites/healthcare/files/1258418522196.pdf>

Another international example of a regional community study in an area where intensive coal mining will eventually occur is the Waterberg region of South Africa.

**MINE:** Waterberg coal field

**LOCATION:** Witbank, South Africa

**BRIEF DESCRIPTION/BACKGROUND:** Underground and open pit coal mining. Coal contributes 93% of the total electricity consumed in the country. Rapid economic growth and a massive electrification programme have resulted in an energy crisis in South Africa. To contribute to meeting the energy needs of the country, plans are in place to develop the Waterberg coalfields to fire new power-stations, and other energy-delivery technologies. These plans will not assist in realising government commitments to reduce carbon emissions in the medium term.

Current plans for the Waterberg coalfields to the west and north of Lephalale (the largest town and the economic hub of the municipality, and the fastest growing town in South Africa, growing at an annual rate of 30% for the past 3 years) include the expansion of an existing coalmine, to deliver to a power station currently under construction. Possible future developments include additional coal mines, six to nine power stations, and other water intensive industries that require coal.

**AREA OF LEADING PRACTICE:** Resource efficiency; Community engagement

**HANDBOOK(S) REFERENCE:** Community Engagement

**DESCRIPTION OF INNOVATION:**

Sustainable development particularly in the South African context requires the integration of many factors, including issues relating to economic, social and financial matters, human, environmental and man-made/manufactured assets. These aspects are all linked in a complex system, so that changes in one factor can have effects on other factors, directly and indirectly, as well as cumulatively. Finally, when charting a path for sustainable development, we are required to look far into the future to ensure intergenerational equity, one of the underpinning elements of sustainable development.

The multiplicity of factors to be considered, the long time-horizons that are involved and high levels of uncertainty suggest that conventional planning practices cannot yield the necessary results for sustainable development. In such situations scenarios can be more useful in informing decision-making and learning in situations of high uncertainty. Scenarios can help to interpret and deal with change, assist planners to anticipate crucial events and open new possibilities and insights. Via systems thinking, scenarios recognise that many factors may combine in complex ways to create unexpected futures. Scenario development is therefore well suited to any futures-thinking related to sustainable development.

The scenarios envisaged for the Waterberg were conceptualised at high level, supported by a desk-top level fact base and were informed by a series of indicators chosen as representative criteria for “success”, available in the fact base. The scenarios are presented as stories about the coalfield area, focussing on Lephalale (formerly Ellisras), at some time in the distant future, when the coal reserves have all been exploited to their maximum potential and the mining operations have mostly closed or are closing. The starting point for all the possible scenarios is of course today, and the current context of the Waterberg is summarised first as the springboard for the developments and related settlement scenarios.

Findings from the study indicate that some of the potential problems that might arise are already evident. This can be seen in the “Business as Usual” scenario. The platinum mining area and the Mpumalanga coalfields were used as proxies to substantiate the findings of this study. Significantly, both proxy areas are characterised by dispersed settlement patterns and are associated with negative environmental and socio-economic impacts. The socio-economic impacts relating to each scenario are described qualitatively within each scenario: a quantitative summary is also provided (see CSMI 2010).

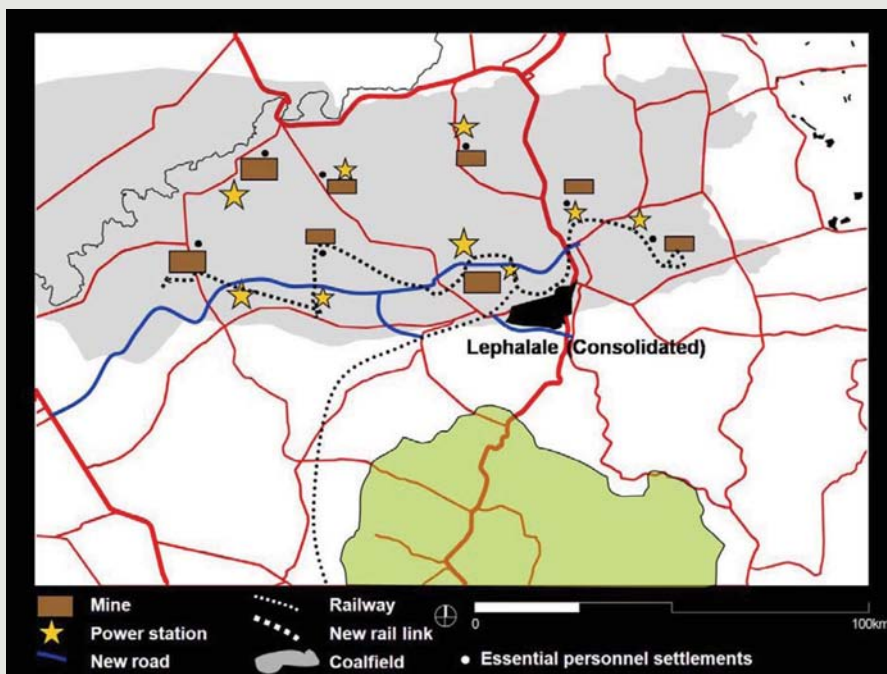


Figure 2.6 - The Recommended Scenario - The “Beautiful Game” Spatial Pattern

**Reference:** CSMI August 2010 “Sustainable Development of the Waterberg Coalfields - Scenarios for Optimal Settlement Patterns”

\* contributed by Prof May Hermanus, CSMI, University of Witwatersrand



## Engaging with women

The significant role that women play in decision making, particularly in indigenous societies, is becoming recognised by many enlightened mining companies. The need to engage with women during the earliest stages of a project is essential. The following case studies illustrate leading practice in engagement with local women in Indonesia and Papua New Guinea.

**MINE:** PT Kaltim Prima Coal

**LOCATION:** Eastern Kalimantan, Indonesia

**BRIEF DESCRIPTION:** Mainstreaming of gender in KPC's Community Development Programs through a 'Participatory Action-Research' project from 2006 till 2010.

**HANDBOOK(S) REFERENCE:** Community Development/CSR

### DESCRIPTION OF INNOVATION

Incorporated in Indonesia in 1982, PT KPC was originally owned jointly by BP and CRA Ltd, but was sold to Bumi Resources Limited, an Indonesian-owned company (see for details [www.bumiresources.com](http://www.bumiresources.com)) for US\$ 8.8 billion in 2003. In 2007, the fully Indian-owned, Tata Power Company purchased 33 per cent equity of Bumi Resources Limited. In recent years, KPC coal productions have expanded tremendously—from 19 million tonnes in 2003 to 48 million tonnes in 2010. When KPC reaches its target production of 70 million tonnes in 2015, it will be by far the largest coal producing mine in the world.

KPC is the earliest and the largest of the mining companies that operate in a sensitive equatorial environment of the region. A relationship of dependency, or a patron-client relationship, had emerged between the Company and the community. Currently, KPC owns a series of twelve open cut pits (only seven are currently under operation), two coal preparation facilities, a 13 kilometre overland conveyor to the coast and two marine terminals capable of handling bulk ocean carriers in the town. It also owns almost all the supporting infrastructure in the area. Consequent to the leap in production, negative effects on the community increased, making women and youth more vulnerable than before.

The project addressed the key question: 'How can local communities in the mining regions of developing countries derive sustainable benefits from the presence of a large-scale mining operation? More specifically, the Project asked: 'How can the empowerment of women within mine-affected communities contribute to the development of sustainable local livelihoods throughout and beyond the life of a large-scale mining operation?' Theoretically, these questions are located at the intersection of three fields of recent debates:

1. Studies of the social impacts of mining on rural, remote or indigenous communities.

2. Reflections on the significance of community development projects and programs within the framework of Corporate Social Responsibility and the 'Triple Bottom Line' and
3. The application of gender and Development (GAD) principles to social and economic processes triggered by mining that generally exacerbate gender inequalities within affected populations. The inclusion of a GAD-based approach in Community development was the unique component of this project and offers a model for emulation by other companies.

The participatory Action-Research Project aimed to create cooperative working relationships with the women and men in mine-impacted communities. The objective was to produce practical knowledge and effective, gender-equitable, outcomes that can benefit all stakeholders. Working together with the community, the study produced gender analyses of the local context, before and after CD project intervention; gender needs assessments in villages; assessment of specific programs run by the Company; gender-based Monitoring and Evaluation of existing CD projects, gender sensitization and capacity-building for Company Staff, and the development of new CD programs that aim at women's empowerment. Almost all reports and studies are available from the project website: [www.empoweringcommunities.anu.edu.au](http://www.empoweringcommunities.anu.edu.au).



Figure 2.7 - Women Farmers in the Villages

\* Contributed by: Dr Kuntala Lahiri-Dutt

**LOCATION:** Papua New Guinea

**BRIEF DESCRIPTION:** Women in Mining (WIM) program address gender inequities in the distribution of mining benefits through empowerment and capacity building of women.

**AREA OF LEADING PRACTICE:** Gender and community development

**DESCRIPTION OF INNOVATION:** Global experience shows that the mining sector is gender-biased, where mining-related benefits such as employment and income are largely captured by men and the brunt of the negative impacts of mining (social and environmental risks) largely fall upon women, while sharing disproportionately less of the benefits; the mining sector in PNG is no exception.

The WIM activities have helped to build linkages between networks of key women at the national level and women's groups at local level; to build the capacity of local women's associations, and have given them greater voice with *male community leaders and local governments*; and have helped *mining companies* to target their community programs more effectively with improved outcomes .

Lessons learned from the Women in Mining program include:

- Using a gender lens to understand the benefits and risks of mining projects can help identify actions to improve overall development outcomes.
- Supporting women's needs and requests can help build strong local ownership among local women.
- Listening to women's voices can empower women to take a more proactive role in community affairs, and can empower women to then help others in their communities.
- Informing community women about mining helps them to become engaged in the assessment of the impacts of mine development.



Figure 2.8 - Porgera Mine

Contributed by: World Bank

## **Engaging with Indigenous communities**

The quest for new mineral-bearing fields is taking more and more exploration and mining companies into areas occupied by Indigenous communities. Although the following discussion will focus on the Australian situation, the same basic principles can be applied in North and South America, the Pacific, Asia and many other regions.

One of the most important factors shaping the relationship between exploration and mining companies and Indigenous communities is the ability of the parties to communicate effectively with each other. Mining companies and Indigenous communities have their own unique cultures and building strong relationships between the groups is dependent on each party understanding that the other operates within a very different value system. Without this shared understanding, it is difficult to develop enduring relationships that will enable both cultures to coexist amicably, or to manage effectively the issues that arise when mining companies and Indigenous people are working together.

The development of enduring and sustainable agreements and relationships are dependent on the mining industry and Indigenous people recognising the importance of cultural differences and exploring ways to adapt, modify, and change cultural practices. The challenge for mining companies and Indigenous communities is to change cultural practices in ways that meet the culturally important or critical needs of one party while accommodating (to the extent possible) the objectives of the other party.

Cultural practices and responsibilities in relation to land estates differ markedly between Indigenous communities across Australia. Exploration and mining companies preparing to work with Indigenous people for the first time will benefit from expert advice about those practices and responsibilities. It is important to acknowledge the many protocols associated with working on Indigenous land, for instance the traditional welcome to country, the difference between women's and men's business, and 'sorry business'. Prudent practitioners would seek expert advice on these matters. One situation where advice may be particularly important is when it comes to negotiating land access. Mining companies need to ensure that they are talking to the 'right' people, that is those with culturally appropriate responsibilities for country and with the authority to 'speak for country'.

On occasion people may assert such authority when that authority has not yet been widely bestowed or acknowledged according to custom. Similarly, it is also important to understand that, in some parts of Australia, the Indigenous people who have land management responsibilities based on historical connections to the land may be different from the Traditional Owners of that land according to culture.

Apart from cultural norms relating to land ownership, management and access, there are many other Indigenous cultural beliefs and practices that may conflict with mining industry norms. It is important for mining companies to understand these cultural differences if companies are to engage successfully with Indigenous communities. For example, there are social customs that Aboriginal people cannot ignore, such as the need to attend funerals, even though their frequency and importance may be difficult for mining personnel to understand.

Similarly, the need to avoid direct contact with some community members, designated by custom, may be required. Another important example is that Aboriginal community decision making follows cultural norms of consensus based on iterating sub-group discussion and general assembly. Hence the pace of decision making can be slower than what a mining company might prefer and yet, without such a process, any expedited decisions may not stand the test of time. While it is not necessary to understand in detail what these customary norms are, mining companies need to understand they exist and seek expert and local help to work within them.

The coal fields of India are located within densely populated areas where local people have lived for generations. The following case study illustrates a new approach to resettlement of the local population thus allowing co-existence of mining and other land uses.

**MINE:** Jharia Coalfields

**LOCATION:** Jharkand, India

**BRIEF DESCRIPTION:** Open pit and underground coal mining

**AREA OF LEADING PRACTICE:** Resource utilisation

**HANDBOOK(S) REFERENCE:** Community Engagement; Working with Indigenous Communities

**DESCRIPTION OF INNOVATION:**

As minerals are site specific, mining activity affects the community living on or around the mineral deposit including, both indigenous and non-indigenous land owners or occupiers. In India the mining industry follows the National Rehabilitation Policy. Individual mining companies have their own rehabilitation and resettlement (R&R) policies incorporating the National Policy to take care of the project affected people. The compensation for rehabilitation is decided through a socio-economic survey conducted by the state government administration.

BCCL inherited more than 100 coal mines in Jharia Coalfields (JCF) from private leaseholders after nationalization of coal mines during 1971-73. Most of these mines were facing various environmental problems and issues of rehabilitation and resettlement of people affected by fires and subsidence in these areas. Government of India approved the Jharia Action Plan (JAP) through Gazette Notification of 12th August 2009. BCCL along with Jharia Rehabilitation and Development Authority (JRDA) have initiated the implementation of this approved Jharia Action Plan. Remote sensing and GIS applications have been utilized to relocate and rehabilitate the affected people with modern amenities such as skill development programmes, safe drinking water and proper sanitation facilities.



Figure 2.9 - A New Township under Construction at Belgoria, Dhanbad as per Jharia R& R Plan



Figure 2.10 - Mine Water Augmentation at JCF

\* contributed by: Prof Gurdeep Singh

### **The importance of language in relationship building**

The fact that English is likely to be a third language for many Aboriginal people in Australia and throughout the world creates special challenges for mining companies wishing to build relationships with Indigenous communities and recruit Indigenous employees. Cross-cultural awareness training, for example, is an important tool for relationship building.

The purpose of cross-cultural training in mining companies is to develop mutual respect and understanding between Indigenous and non-Indigenous employees. The most effective cross-cultural training programs are run as part of the induction process for all new employees.

For Indigenous recruits, cross-cultural training introduces them to the expectations of the mining industry, especially in relation to:

- workplace health and safety.
- site entry requirements.
- operational procedures and work expectations.

Cross-cultural awareness training introduces non-Indigenous recruits to industry expectations with regard to:

- recognising and maintaining respectful relationships with Traditional Owners.
- protecting Aboriginal cultural heritage.
- adhering to environmental regulations.

Coming together to learn about each other's cultures is one important way of building relationships between people from different cultural backgrounds. It can also assist the company in its environmental assessment of culturally and ecologically sensitive areas.

Agreements between mining companies and Indigenous people with rights and interests in land and waters are the most practical approach to finding ways to accommodate each other's interests. Many companies now formalise their relationship with land connected to Indigenous people through agreement making, whether motivated by legislative requirement, enlightened self interest and/or risk management. The Australian Government also strongly encourages negotiation of agreements over litigation as the way to resolve mining interface with native title and other Aboriginal land interests.

Agreements allow parties to negotiate outcomes to ensure that they reach solutions which meet their respective needs. Agreements provide mining companies with secure land access, which they need if they are to invest large sums in high-risk, long-term mining ventures. They also recognise the interests of Indigenous people who have maintained strong connections to the land and waters where, as a matter of law, their native title no longer exists, or only survives in a limited way.

The relationship between mining companies and Indigenous communities has improved enormously in recent years. Increasingly, negotiations are focused on mutually beneficial outcomes and the development of sustainable relationships. Both parties have developed new competences in negotiation and engagement and are increasingly focused on developing agreements that will enhance the ability of Indigenous communities to participate in the economic life of the region. An example of the change in participation rate in the economy is provided by Rio Tinto. In the mid 1990s, less than 0.5 per cent of Rio Tinto's Australian workforce was Indigenous much less than the approximately 900 (seven per cent) in 2007 (see LP **Indigenous** p.69).

## Predicting Acid and Metalliferous Drainage

### Introduction

The primary purpose of a geochemical assessment of mine materials is to guide management decisions. Therefore, it is critical that a phased assessment program is carried out to ensure sufficient data are available at all phases of the project cycle. Leading practice can only be achieved through early recognition of the potential for AMD.

Geochemical assessment aims to identify the distribution and variability of key geochemical parameters (such as sulfur content, acid neutralising capacity and elemental composition) and acid generating and element leaching characteristics. A basic screening level investigation is essential and should commence at the earliest possible stage. The need and scope for detailed investigations will depend on the findings of initial screening. Since some studies such as leach tests or sulfide oxidation rate measurements require a long time frame to provide the necessary data, it is important to initiate this work well ahead of key project milestones.

Reference to other mining operations in the region, particularly those situated in the same stratigraphic or geological units may provide empirical information on the likely geochemical nature of similar ore types and host and country rocks. The Pine Creek Geosyncline in the far north of Australia is renowned for its propensity for acid mine drainage potential in virtually all gold mines that operated in the 1970s and 80s.

Early indications can also be provided by exploration drill core where it is leading practice to log key indicators such as sulfide and carbonate type, abundance and mode of occurrence. All samples should be analysed for total sulfur content as a minimum, and include key environmental elements in all drill core assays. Mineralogical investigations should examine the type and mode of occurrence of sulfide and carbonate minerals.

A number of procedures have been developed to assess the acid forming characteristics and metal leaching behaviour of mine materials. The most widely used screening method is based on the Acid Base Account (ABA) which is a theoretical balance between the potential for a sample to generate acid and neutralise acid. The simplest form of the ABA is known as the Net Acid Producing Potential (NAPP).

Some sulfur minerals do not generate acid (but may contribute to metalliferous drainage), and there are different forms and reactivities of AMD generating minerals and AMD neutralising minerals. As a result, there is a level of inherent uncertainty in prediction based solely on the theoretical ABA. Mineralogical investigations, elemental analysis, sulfur and carbonate speciation, acid neutralising capacity, reactivity, and the Net Acid Generation (NAG) test (a rapid direct oxidation procedure) are used to address this uncertainty. AMD prediction is greatly enhanced by using a combination of tests, in particular independent tests such as NAPP and NAG.

### **Sampling**

Sample selection is a critical task and must be given careful consideration at all stages of a project. Samples should represent each geological material that will be mined or exposed and each waste type, for current and projected mine plans. Sampling design normally utilises drill hole cross-sections through the deposit.

The number and type of samples will be site-specific and will depend on the phase of project development, but must be sufficient to adequately represent the variability/heterogeneity within each geological unit and waste type. Factors such as grain size, structural defects, alteration, brecciation, veining, etc., must therefore be considered in sample selection. As a minimum requirement, through the exploration phase to final feasibility, all drill hole samples should be assayed for total sulfur.



Although drilling and sampling will focus on ore zones in the exploration and pre-feasibility phase, samples of host and country rock should be increasingly represented as the project develops so that adequate data are available to produce block models and production schedules by geochemical waste types.

Key sampling guidelines are listed below (Scott et al., 2000):

- Drill core and percussion chip samples should represent no more than 10 metre intervals and cover individual geological types and ore types.
- Each composite sample should not be obtained from more than one drill hole.
- Each sample should be approximately 1-2 kg. The sample should be crushed to nominal 4 mm size, then riffle split to produce 200-300 g for pulverising to minus 75 micron. The minus 4 mm and pulverised splits should be retained for testing.

### **Pre-mining**

Few mineral resources are homogeneous and relatively little is understood about them and their host rocks in the pre-mining phases. However, it is important during the pre-mining phases that the project team, including geologists, mine planners, environmental scientists and AMD experts, ensures that an adequate geological and geochemical database is compiled to clarify baseline conditions and the risk of AMD. A typical progressive test work program is summarised in Table 3. Knowledge of the likely wastes that will be generated and materials exposed and the constraints that these will place on the mining operation is vital (Scott et al., 2000).

A detailed Closure Plan needs to be developed and costed for a site during the feasibility phase. This must remain a “living document”, as the mine proceeds, with regular reviews and updates based on new technologies, stakeholder inputs, changing mine conditions and community expectations.

### **Monitoring Purpose**

The main purpose of an AMD monitoring program is to provide relevant information that can be used by site planners and managers as a basis for informed decision making. An effective monitoring program will facilitate the implementation of an AMD Management Plan for the site that can reduce or eliminate the impacts of AMD on the environment, community and mining operations.

Regardless of the project phase (exploration through to operations) there are a number of issues to consider when developing a monitoring program. Typical elements of an AMD monitoring program, during exploration/feasibility and operations, are outlined in the Leading Practice handbook on Managing Acid and Metalliferous Drainage. However, monitoring programs need to be site-specific and take into consideration the phase of project development and the sensitivity of the surrounding environment and community. Other key points to consider are:

- The nature of the material being handled, including volumes and reactivity.
- Likely composition of leachate generated from the material.
- Likely downstream receptors and baseline concentrations of significant analytes.
- Turnover of material including rate and the ability of personnel to access the material.
- Sampling technique, preparation and preservation requirements.
- Maintenance of sample integrity and chain of custody.
- Reference to appropriate guideline limits.
- Turnaround times for both the material being mined and analyses. If the turnaround of material being mined is relatively short, then analysis techniques need to be applied which allow for a rapid turnaround of data.
- Representative sample size.
- Government regulations and licensing requirements.

The monitoring program should provide information to facilitate leading practice AMD management in the short and long term. It is essential that monitoring data are usable and that a solid communication forum exists between environmental monitoring staff and site planners and managers. Careful interpretation of monitoring results is also critical for the ongoing development and implementation of an AMD Management Plan. If management practices are not effective then actions need to be taken to rectify the situation before long term impacts arise. A quick resolution will often prevent excessive acidification before it becomes impractical or cost prohibitive. Education and involvement of the workforce is essential to the successful management of AMD issues.

The benefit and importance of gathering an extensive sulphur and multi-element database from drill core during early stages of project development is clearly illustrated from Rio Tinto's **Sari Gunay** project in Iran. A resource model database consisting of more than 15,000 sulphur and elemental assays on one metre intervals of drill core was compiled during exploration, pre-feasibility and feasibility studies. These data identified the presence of sulphur within waste rock and ore as an issue for the project because of the potential for generation of acid rock drainage and contamination of water resources (LP **AMD** p.33).

To evaluate the acid rock drainage risk, 101 drill core intervals were carefully selected to represent the likely variability within each geological rock type and assayed for sulphur, ANC and NAG. The results indicated that about one third of the waste rock will be NAF and two thirds will be PAF, with only a small amount of High PAF mined and this will all occur in the last year of operation. NAF rock is produced up to year 7 and from year 8 to the end of mine life at year 11 all waste rock will be PAF. The schedule identified a need to re-handle NAF material to allow encapsulation of all PAF waste.

The selected design option is to incorporate all waste rock within the tailings dam and embankment to facilitate tight control on materials placement. All High PAF will be placed within the tailings storage and all PAF waste will be placed, compacted and encapsulated within the embankment. This case study demonstrates that prediction and quantification of AMD issues early in project development allows control strategies to be integrated with mine planning and engineering design to minimise long-term AMD liabilities.



Figure 2.11 - Sari Gunay project in Iran

## Evaluating Performance: Monitoring and Auditing

### 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 of the Leading Practice Monitoring handbook. 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.

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. 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.

### 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.

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.

**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. 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.

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 (see LP **Monitoring** p.19).



Figure 2.12 - Hail Creek mine site

### **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 & ARMICANZ 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 of the Handbook, monitoring data are often the most valuable asset of a mine environment section, and built-in obsolescence should be avoided as much as possible. The Tampakan case study provides an excellent example of commencing a monitoring project as early as possible - in this case some years before the commencement of production.

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.

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. 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 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 (see LP **Monitoring** p.76).



Figure 2.13 - Sampling activities in the Tampakan area

## Mine Closure

### Planning for Closure

Planning for mine closure should be undertaken progressively throughout an operation's life cycle. The amount of detail will vary and refocus on specific issues through this life cycle. In order for mine closure planning to be successful, the management team needs to ensure it is integrated early into planning rather than being attended to at the end of mine life. The initial ground work, even at the exploration phase, can impact on the effectiveness and success of closure planning. To ensure optimal results, it is critical that community and other stakeholder engagement occurs throughout the process of planning for mine closure.

In many states or territories, a preliminary closure plan is required by the regulatory authorities as part of the approval process. This plan is used to assess the project, the environmental controls required and the long-term potential liability posed by development of the mine. Typical issues that should be included in the feasibility assessment include:

- potential area of disturbance.
- environmental sensitivity of flora and fauna, surface and groundwater quality.
- volumes and types of wastes to be stored, including waste rock and tailings.
- characterisation of wastes including geotechnical properties and AMD potential.
- appropriate locations and required capacity of water storage facilities for potable consumption, process supply, and site water management.
- geotechnical stability of ground surface and engineered structures.
- regulatory requirements for design and closure.
- proposed designs for waste storage facilities and costs to rehabilitate and close.
- social and economic development and sustainability issues, such as local enterprise, post-closure use of land and infrastructure, and other community development programs.

## Risk Management and Exploration

Exploration is a high risk activity. In the 1960s, Canadian researchers found that to produce a commercial mine, around a thousand mineral prospects are investigated, of which only a hundred are drilled for reconnaissance and only ten progress to intensive drilling. Modern exploration may have altered the ratios but not by much. Such figures highlight the high commercial risk and low success rate of exploration throughout the world (Environment Australia 1995).

Effectively applying risk management principles early lays the foundation for good relationships throughout the whole mine life cycle. There are many examples of relationships being damaged at the exploration/discovery stage or during mine feasibility. This creates difficulties for stakeholder relationships that can carry through to the construction, operational and closure phases of mining and may require significant additional management effort, delay project start-up or adversely affect the life of the mine.

One method of incorporating risk planning into a mineral project's 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 ISO14001:2004, or any other mechanism for managing impacts) (see LP **Monitoring**).

## Water Management Planning

### Introduction

Access to water is a fundamental human right. The communities within which industry operates, or impacts upon, expect and demand that: (1) they be involved in decisions regarding the allocation of water resources, (2) industry uses water efficiently, and (3) industry does not negatively impact on water quality.

Traditionally, community and other stakeholder consultation have been undertaken during the environmental assessment and project approval stage. Engagement with local catchment management authorities and other stakeholders during development and review of catchment water sharing plans should be sought. The dialogue around water use and allocation has had to deal with allocation of a scarce water resource between competing users. On a purely value-adding criterion (dollars generated per megalitres of water used), mining and minerals processing adds significantly more financial value per volume of water consumed than all agricultural uses (ACIL Tasman 2007). Under certain conditions in some jurisdictions water markets or contracting arrangements can be over-ridden to enact a hierarchy of use which includes domestic or town water, the environment, stock water, agriculture and industry. In the more remote areas, where the economic competition for water may not be as direct when compared with those operations in close proximity to urban areas and agricultural enterprises, the cultural and environmental values of water can be significant drivers. Sites may have opportunities to contribute positively by working towards maintenance of values.



Many examples exist where mines provide water to community members. This can range from stock and domestic uses to formal supply of larger volumes for irrigation through infrastructure designed, constructed and managed by the mining company. For example, the Bingegang pipeline in Central Queensland supplies many stock and domestic users along its path of several hundred kilometres. Cadia Valley Operations manages onsite raw water storages to ensure downstream flow targets are met to supply agricultural needs (see LP **Water** p.44). Water supply can also be part of agreements associated with dewatering. This can occur through 'make good' agreements connected to changes in hydrological conditions caused by the mine.

Prior to, during, and post operations there is a need to understand the community environment—how water is used, who uses the water, seasonality of use, and existing and future stakeholder and community demands. Ongoing dialogue helps these communities understand the mine's water needs and for the industry to understand community expectations when making business decisions involving water use. Few communities surrounding mines will have an intuitive grasp of the concept of mine closure. Therefore, it is particularly important that this concept is explored with the community early in the operation and that closure planning involves community throughout. This will minimise long-term legacies with communities over unrealised expectations post closure.

Community consultation and engagement techniques are discussed in the Leading Practice Sustainable Development Program's Community Engagement and Development. Given the sensitivity of water for livelihood, environment and cultural support, a great deal of community engagement is likely over water-related issues, as illustrated in the Iluka case study.

### **Water Management Plan**

A comprehensive site Water Management Plan (WMP) is fundamental to leading practice water management. Its size and complexity depends on the nature of the operation, hydrology, and the cultural and environmental sensitivity of the surrounding area. It is a public statement about how to manage both operational use of water and potentially adverse impacts of operations on the local and regional water resources. The WMP identifies all water management issues associated with developing, operating and decommissioning a project. The main water issues to be covered at each stage of the life cycle (see Figure 2.14) are summarised in Figure 2.15. Water quality issues during exploration and other phases of the mining cycle are summarised in Table 2.

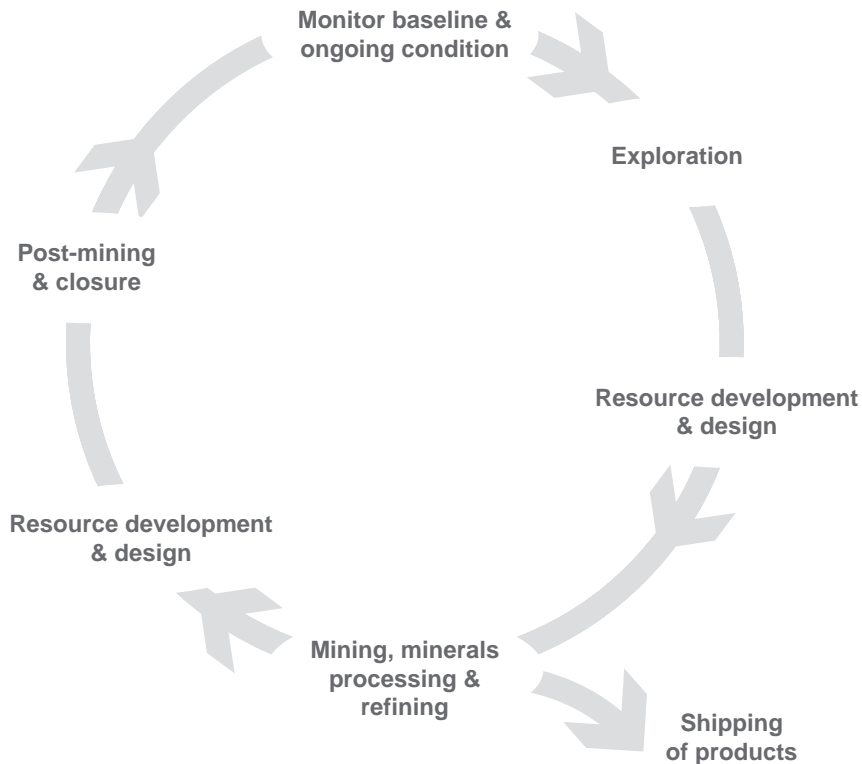


Figure 2.14 - The main operational phases in a mining operation life cycle and the main water issues in each phase. Interactions with surrounding community and environment must be actively managed at all life cycle stages.

### I. Exploration

- Temporary water supply
- Impacts of water management on local water resources/users
- Potable water treatment
- Discharge of excess drilling water
- Waste water disposal
- Site stormwater management

### II. Resource development & design

- Water supply – Identification & quantification
- Impacts of water abstraction/diversion on local water resources/users
- Government approvals
- Water supply, storage & treatment (design & construction)
- Dust suppression and dewatering discharge
- Waste water disposal
- Site stormwater management

### III. Mining, minerals processing & refining

- Water supply management
- Water treatment [worked water & potable]
- Mine dewatering
- Worked water recovery, storage and reuse
- Worked water disposal (discharge management)
- Dust control and contamination management
- Catchment management (including AMD)
- Performance monitoring and reporting

### IV. Shipping of products

- Spillage, dust control

### V. Rehabilitation

- Post-mining landform drainage design
- Contaminated site remediation
- Borefield and water supply scheme decommissioning
- Decommissioning of mineral processing and transport facilities
- Mine pit lake modelling and formulation of closure strategies
- Stakeholder approval and development of catchment management plans

### VI. Post-mining and closure

- Rehabilitation performance monitoring
- Erosion control & drainage maintenance
- Contaminated site remediation verification
- Stakeholder and regulatory sign-off

Figure 2.15. Activities at various stages of a mine's life cycle.

Table 2. Typical water quality issues for the mining industry

Mine-life stage	Water quality related activity	Action
Exploration	Erosion from temporary roads Runoff of drilling fluids, petroleum products from drill pad construction and operation, camp wastes.	Initial baseline monitoring program developed (weather station, several water quality/biology sites, water flows).
Resource development and design	Developing water management plan. Preparing EIS.	Baseline inventory and monitoring at key sites, including those in reference catchment(s), implemented for water quality and ecological features.
Mining, minerals processing and refining	Discharge management. Possible acid-rock drainage. Tailings management. Solid waste management.	On-site monitoring (discharges, storage and holding dams, groundwater) Off-site monitoring of receiving system and reference sites (quality, flows, biology). Water management plan implemented.
Rehabilitation	Management of onsite water.	On-going assessment of impacts.
Closure and post-mining	Considering all possible future impacts (e.g. acid rock drainage).	Continued off-site and onsite monitoring.
Shipping of products	Possible spillage, dust control	Monitoring of receiving system and reference sites (quality, flows, biology).

The **Cadia** case study illustrates the importance of collecting data during the EIA and feasibility stages of a mining project. The Cadia Hill gold mine was approved on 6 September 1996 with several conditions. These conditions related to the release of water from Cadiangullong Dam and the maintenance of flows in Cadiangullong Creek to provide environmental flows and as well meet the requirements of downstream users.

Limited baseline data on the aquatic ecology and hydrology of Cadiangullong Creek was available at the commencement of the project and additional data was collected as part of the environmental impact studies. At the time of the construction of the Cadiangullong Dam, empirically based processes for determining the riparian and environmental flows needed to maintain riverine ecosystem integrity were in their infancy in Australia. Virtually no research had been undertaken on these issues in small upland streams.

Additional research was required to be undertaken to assess and model the effects of changing flow regimes (drought, low, medium and flood) on in stream and riparian environments and their associated organisms. The Environmental Studies Unit at Charles Sturt University was contracted by Cadia to design and carry out appropriate research to satisfy the requirements of this condition. The researchers concluded that there was no evidence of a decline in stream diversity and that under the range of flows available during the study period, a very high

level of family diversity was maintained (see LP **Water** p.44). As it turns out some 12 years after commencement of the mine, water has been the most significant environmental issue. In 2009, the mine was almost forced to temporary shut down due to a lack of water.



Figure 2.16 - Cadiangullong Creek Dam



Figure 2.17 - Rio Tinto Aluminium Yarwun alumina refinery. Image Source: Rio Tinto

## 3.0 DEVELOPMENT AND CONSTRUCTION



3.1 - Mt Todd mine, Northern Territory, Australia during the construction period (1996)

### Key Messages

- Workforce levels and surface disturbance can peak therefore the social and environmental impact can be higher than any other stage
- When risk management is not undertaken thoroughly, it can lead to major flow-on impacts on an individual mine, company and the mining industry
- Sustainability requires that the complex relationships between various risks be well understood, especially the potential for links between environmental, social, political, economic and reputation risks
- Community engagement activities should be a continual (daily) focus of senior management in this phase
- Contractors and subcontractors will likely outnumber company employees and require continual management attention if sustainability objectives are to be achieved
- Opportunities for Indigenous participation in the workforce should be pursued
- Planning and development for an effective monitoring framework should occur as early as possible in a project's life cycle

## Introduction

The development and construction phase of a mining project is as critical a stage of a mine's life cycle as any other and can often determine how sustainable the operational phase will be. Many projects, as illustrated by the Mt Todd case study, fail at this point. There can be a number of reasons for failure including:

- Peak demand of funds resulting in cost overruns
- Community opposition to the project
- Significant and at times, unexpected environmental impact

In this Chapter, **development** is used as it is typically used in a miner's lexicon to refer to the pre-operational phase of a mine's life. It may include establishment of infrastructure and access works such as decline or shafts to enable production to begin. Once production begins the mine is said to be in the **operations** phase (see Chapter 4).

Construction is in mining terms a subset of the development phase and its activities at a mining project create significant and visible changes and impacts on the environment and community. This short-term stage requires the highest level of employment, which exceeds the longer-term workforce requirements. The influx of a construction workforce can provide economic benefits to the local community, and particularly local businesses, but it can also put pressure on housing and other local services and have a negative social impact on the community.

Construction activities typically include:

- access roads and airstrips.
- construction and accommodation camps.
- power supply (electricity, gas or diesel).
- fuel and chemical storage facilities.
- water supply.
- process plant.
- workshops and warehousing.
- contractor lay down areas.
- offices, change rooms.
- crushing plant.
- tailings storage facilities.
- waste rock, low-grade and other dumps.
- stockpile preparation.

During this stage of a mine's life cycle, activity on site is often at a peak.. The skills required in both management and labour can be significantly different to that required once the mine is producing. The project management team during construction and development is focused on achieving, often under high pressure, budgetary and infrastructure completion goals. Their focus isn't always on sustainability aspects. Moreover, the project team often has a handover to a new team once their role is finished. This in itself can present challenges.

It is during the development and construction phase of a mine's life that many of the decisions are made for the long-term, influencing and impacting on the sustainability of the mine. This chapter provides guidance in managing the sustainability aspects during this critical, pre-production phase

## **The Business Case for Sustainability in Development and Construction**

The purpose of this book and the earlier handbooks is to highlight leading practice. However it can be argued that the most valuable lessons are learned from the mistakes of the past. The Mt Todd mine in the Northern Territory provides one such example. The case study is included here to highlight the wide breadth of sustainability issues and the need for management to be aware of all these issues. Due to a multiplicity of reasons, the mine with an expected life of around 15 years closed after a year resulting in:

- the company Pegasus Gold losing its investment of around US\$350 million in this project and filing for bankruptcy protection in the USA
- a large rehabilitation bill of tens of millions of dollars which was funded by the taxpayer
- significant environmental damage including heavy metal pollution
- poor community relations with the local Indigenous and business community
- loss of numerous jobs

Clearly and with the benefit of hindsight, there was a strong business case for not opening the mine.

**MINE:** Mt Todd

**LOCATION:** Near Katherine, Northern Territory, Australia

**BRIEF DESCRIPTION:** Open pit gold mine

**AREA OF LEADING PRACTICE:** Acid Rock Drainage; Waste rock dump; TSF; Biodiversity; Resource efficiency; Mine closure

**HANDBOOK(S) REFERENCE:** Acid Mine Drainage; Mine Rehabilitation; Mine Closure

**DESCRIPTION OF OPERATION:**

Resource utilisation/efficiency:

This is a classic case of what can go wrong technically did go wrong. The resource was not utilised optimally.

- Head grade
- Metallurgy - harder ore than expected; flotation problems;
- OHS - dust hazard

A summary of the technical statistics is provided below (Rudenno, 1999)

**MT TODD GOLD PROJECT, NORTHERN TERRITORY**

Owner, Pegasus Gold Inc.

Close down, November, 1997

**Write offs**

Acquisition costs	US\$ 122.6 million
Deferred preproduction and development costs	US\$ 49.4 million
Property and equipment	US\$ 181.3 million
<b>Total write off.</b>	<b>US\$ 353.5 million</b>

TECHNICAL DATA	FORECAST	ACTUAL	CHANGE
Reserves	94.5Mt	-	-
Reserves grade	1.07g/tAu	0.96g/tAu	-10%
Met. Recovery	84%	74%	-12%
Tonnes/year	8Mt	6.7Mt	-16%
Crushing costs	\$1.36/t	\$2.49/t	+83%
Contract mining	\$1.00/t	\$1.15/t	+15%
Power costs	\$0.058/kwh	\$0.075/kwh	+29%
Cyanide usage	0.68kg/t	0.86kg/t	+26%
Total cash costs	11.86/t	\$13.58/t	+15%
Tonnes ore/oz. Au recov.	34.6	43.8	+27%
Exchange rate A\$1.00=US\$	0.7	0.74	+6%
Cash costs/oz Au recov.	US\$287	US\$440	+53%
Gold price/oz	US\$385	US\$315	-18%



## **SUSTAINABILITY IMPACTS**

### **Biodiversity:**

The focus of the EIA was on preserving the habitat of the Gouldian Finch, an endangered bird (see figure 10). Despite this focus, during the construction period a contractor destroyed 14 ha of vegetation in the Yinberrie Hills adjoining the new waste dump. The site contained several breeding hollows in a salmon gum woodland. The outcome was outrage from the community including the Gouldian Finch society and the mine was almost closed by the regulator.

### **ARD:**

Although not identified as a major issue in the Environmental Impact Assessment, acid mine drainage proved to be the major environmental issue on site. Sources include the open pit itself, and the waste rock (see figures)

### **Tailings:**

The tailings storage facility developed leaks soon after commissioning.

### **Community engagement:**

The joint venture between the mining contractor and the Jawoyn Indigenous community that promised so much in terms of jobs and opportunities, ceased prematurely. The outcome was a lack of trust between the local community and mining companies.

### **Safety:**

Although the safety record during construction was very good, one tragic incident occurred when an employee, who could not swim and was unfamiliar with conditions in the Top End, was washed off a bridge and drowned when he attempted to cross a swollen creek during a flood. He was driving to the mine site one morning.

## Airborne Contaminants, Noise and Vibration

### Air

During the construction phase, there is a range of activities, such as earthmoving and road construction, which generate dust, possibly at higher levels than during the operational stage, at least for parts of the project site. If those parts of the site are close to sensitive areas, attention will need to be given to controlling dust emissions, especially under adverse dry and windy conditions. Any baseline monitoring will continue through this stage. Also, if there is a potential for dust impacts on neighbours arising from construction, the situation may warrant the installation of one or more dust-monitoring instruments which can be used (at the boundary or at the sensitive location) to capture real time data and send an alarm when a predefined dust concentration is reached. In this way, activities can be controlled to minimise short-term dust events in response to the early-warning capability. These types of instruments are not compliant with regulatory standards and cannot be used for compliance monitoring, but are very useful for real time management.

### Noise

Leading practice mandates the implementation of a comprehensive monitoring and audit program during the construction, commissioning and operations phase, and even the closure and rehabilitation phases. The monitoring program provides the mining company with a means to maintain a continuous record of environmental noise emissions. Technology also allows the mine manager to have real time access to data, from monitoring locations at residences around the mine, on which operational decisions can be made. The audit program also addresses the company's procedures for dealing with complaints and ensuring quality objectives are met.

Ventilation fans are essential in underground mining but have the potential to cause significant disruption to the lifestyle amenity of the community. The following case illustrates the measures that can be undertaken to reduce the community impact and implement leading practice. Sinking a 315m ventilation shaft is challenging enough and when you place that project in a residential area of a regional city you need to do your homework.

Ballarat Gold started planning for the ventilation shaft in 2006, well before the planned construction commencement date of July 2006. With some Ballarat residents as close as 60m from the worksite, significant effort was put into planning to minimise the impact on the neighbours. Extensive consultation with the community was undertaken prior, during and after each phase of construction. One on one consultation with the immediate neighbours took place during the early planning stage using diagrams of each phase. Each neighbour was asked if they had any concerns, with most being concerned about potential blast vibration, noise, work hours and dust.

The company has a long history of good community engagement, so many of the community were interested in the project and supportive. The information gathered from community surveys was incorporated into the final plans. For example, the site layout was changed to accommodate two neighbours, moving parking bays, installing visual screens to ensure car lights did not shine into the neighbour's

property and moving a tipping bay to reduce dust and noise impacts. LGL Ballarat strives to minimise the impact on the community rather than simply achieving the compliance limits set by regulators. For the shaft project the company set internal targets well below compliance levels for blast vibration. For example the internal limit for Peak Particle Velocity was 3mm/sec, which was less than a third of the regulatory compliance limit of 10mm/sec.

Several of the neighbours had concerns regarding cracking of their houses from the blast vibration from the shaft sinking operation. To provide assurance to these neighbours the company commissioned house inspections by a qualified independent building inspector, during the planning phase.. Four investigations were undertaken prior to commencement and two during the project. These inspections and additional monitoring undertaken by LGL gave residents peace of mind that there was minimal chance of damage occurring to their properties.

One of the key learning's from the project was the benefit of a spoken telephone text message service to warn residents immediately prior to blasting. Many of the residents were startled by the blast vibration and noise and simply alerting them five minutes prior to firing, alleviated this issue (see LP **ACNV** p.90).



Figure 3.2 - View of the worksite showing proximity of residents

## Biodiversity Management During Development and Construction

During the construction phase, effective management of contractors is also an essential aspect of leading practice biodiversity management (see Mt Todd case study). Increasingly, strict obligations are placed on construction companies to implement their own environmental management systems (EMS) to deliver to the mine owner's standards, including:

- the protection of vegetation and watercourses (no clearing outside designated areas).
- the control of pests (no pets, wash down of all vehicles).
- disruption of wildlife (for example, restricted access to areas).
- waste management.

Leading practice mining companies evaluate construction contracts on the basis of the contractor's past performance and audits of the contractor's environmental management programs, systems and performance.

The development of linear infrastructure such as roads, pipelines and overland conveyers associated with mining projects can impact on a wide range of ecosystems. Disturbance of habitats can occur during construction. Ongoing impacts can also result, such as barriers to wildlife movement, road kills and water pollution from runoff. The movement of animals across the landscape is not uniform. Identifying favoured crossing points and installing under infrastructure access, road signage, speed limits, rumble strips or other measures can greatly reduce wildlife impacts.

For control of other diseases and weeds, construction materials and equipment should be thoroughly inspected, disassembled if necessary, and cleaned prior to arrival on and departure from the site. Attention should be given to imported machinery, or machinery that has come from at-risk areas. The high cost of control methods is justified when measured against the cost of their impacts on economic, social and environmental (including biodiversity) values.

## Community Engagement During Development and Construction

Table 3.1 lists some examples of community engagement and development activities that can be taking place during the development and construction stage of a mine's life.

Table 3.1 Community Engagement and Development during Project Development and Construction

Project stage	Examples of community engagement activities	Examples of community development activities
Project development	<p>Engaging in further discussion and negotiation for the purposes of:</p> <ul style="list-style-type: none"> <li>• ongoing permission for access to land</li> <li>• fulfilling the obligations of land use and other agreements</li> <li>• identifying cultural issues that may extend beyond exploration such as mapping exclusion zones, active protection of sites.</li> </ul> <p>Providing information regarding project development particularly when project development is uncertain.</p> <p>Involving the community in baseline monitoring of environmental and socio-economic and cultural aspects.</p> <p>Establishing consultative forums and structures (such as community liaison committees).</p>	<p>Undertaking community needs analyses and baseline studies, including understanding community capacity to cope with change, and the strength of community networks and institutions.</p> <p>In collaboration with key stakeholders, planning the company's community development programs which may include:</p> <ul style="list-style-type: none"> <li>• establishing trusts and foundations to manage royalties, and/or corporate community contributions</li> <li>• supporting and/or contributing to improvements in community infrastructure (such as schools, housing)</li> <li>• outreach programs for marginalised groups</li> <li>• building the capacity of local and Indigenous businesses to provide products or services to the facility</li> <li>• building the capacity of local and Indigenous people to gain direct employment at the facility.</li> <li>• Liaising with governments about regional development planning.</li> </ul>
Construction	<p>Understanding and addressing community concerns about the environmental and social impacts of large-scale construction activity.</p> <p>Dealing with community expectations about employment and economic opportunities in the construction phase and beyond.</p> <p>Liaising with near neighbours to manage amenity and access issues.</p>	<p>Implementing programs to help integrate employees and their families into the community.</p> <p>Partnering and collaborating with government and other organisations to ensure the delivery of improved services (such as childcare, education, housing) to communities impacted by construction activity.</p> <p>Providing employment, training and business opportunities for local people in the construction phase and beyond.</p>

Rather than taking a generic approach, companies should employ a combination of engagement processes, formal and informal, that encourage different members of a community to engage in ways that suit them. The choice of mechanism will depend on the community, complexity of the method, the issues involved, levels of literacy, cultural appropriateness, gender considerations, resources available and the stage of the project. The choice of mechanisms will also be informed by the processes outlined above.

Offering a variety of vehicles, such as those in Table 3.2, increases the likelihood of engaging a diversity of people, from powerful influencers to people who are impacted and affected but have not traditionally engaged in public dialogue, such as marginalised groups.

Table 3.2: Engagement processes

<b>Informal</b>
<b>One-on-one impromptu discussions and informal conversations:</b> These are important for forming and maintaining relationships, understanding personal perspectives and gaining an appreciation of general community sentiment. Valuable information can be obtained from informal interaction with community members. However, companies need to recognise that informal engagement with just a few individuals may be perceived as favouring the views of particular individuals. In such circumstances there may be greater benefit in first establishing open, transparent and public forms of engagement.
<b>Formal/structured</b>
Combining informal and formal mechanisms provides greater depth to engagement programs.
<b>Public displays:</b> In the early stages of a project, posters and models of proposed operations displayed in public locations, such as retail centres, councils and local fairs can expose the project to many people and raise public interest in a project. Mobile displays can be used in remote locations. Feedback should always be sought.
<b>Briefings:</b> Regular briefings of community stakeholder groups, such as the local media, government personnel, Indigenous leaders and employees are an important way of disseminating information. Presentations should be tailored to meet the information needs of each group. Translating information into other languages may also be necessary in some cases; for example, when communicating with traditional Aboriginal communities.
<b>Public meetings:</b> These may be useful in smaller communities; however, they require careful organisation, often with a skilled facilitator, to ensure that everyone has the opportunity to voice concerns and interests.
<b>Visitors centre:</b> Establishing or providing materials at a visitors centre can provide the local community with easy access to information about the operation, and can also serve as a venue to hold community meetings or briefings.
<b>Contact points:</b> Some sites operate 24-hour telephone lines for providing information and as a method for recording complaints and issues.
<b>Direct mail and newsletters:</b> These are effective for informing specific people about the project, including how the company is responding to community concerns. Correspondence may be personalised, with supporting information, or it may be a regular newsletter describing community activities that the company is involved in.
<b>Community liaison and advisory groups:</b> Community liaison or advisory groups established specifically for the mining project can help the operation focus its engagement program. See the Ravensthorpe Nickel and Martha Mine case studies in this handbook. Groups can cover general matters or be focused on a particular aspect (establishing a community funds foundation, planning mine closure, rehabilitation). The success of these groups will depend heavily on how they are structured and whether their role is clearly defined and understood.

<p><b>Websites:</b> The internet is effective for providing general information about the project and providing ‘real time’ updates on activities and progress. Some stakeholders may prefer the option of engaging through this technology or at least have the option of gaining information this way.</p>
<p><b>Workshops and focus groups:</b> Workshops enable company personnel to work with a variety of stakeholders to brainstorm solutions to issues raised by the community that may not have been adequately considered in project design.</p>
<p><b>Research:</b> Various forms of research, whether undertaken directly by the company or operation, or commissioned from a third party, can provide valuable information about community needs and perceptions about the facility. A range of research methods may be used, from surveys and focus groups to interviews.</p>
<p><b>Scheduled personal visits:</b> Face-to-face discussions are important for establishing personal rapport with key individuals, such as fence line neighbours.</p>
<p><b>Open days and site visits:</b> These activities are a valuable mechanism for keeping the community and families of employees up-to-date about the operation and how it is being managed. Such events also provide an opportunity to hear about community concerns and issues. Site visits for particular stakeholder groups are a more focused and targeted option and can often serve to demystify what happens at a project.</p>
<p><b>Staff membership on community groups and committees:</b> Developing links between mining operations and other community groups can help community understanding about the project, and also help the project understand more about community priorities and sentiments about the operation.</p>
<p><b>Employee interaction:</b> Employees are a valuable resource for understanding community concerns and issues. They are also one of the most important ambassadors of the company and need to be engaged with in a variety of ways, from toolbox talks to more structured employee forums.</p>

## Key steps for sustainable community development

Historically, the industry’s contribution to the community was often managed by outside planners without the involvement of people in the local community. Planners, who may have been mining company managers, consultants or government officials from national or state/territory governments, tended to inform communities of what programs were available for them and sought their agreement rather than their participation. International leading practice in community development—including World Bank requirements—calls for communities to be included in planning processes, and encouraged and supported to participate to the extent of their interest and capabilities. Involving community members, both women and men, in the actual planning stages of development programs, will make success much more likely.

Development work is complex and fluid in nature, and can be approached in diverse ways, but there are some logical steps.

### Step 1: Dialogue

The first step starts with community engagement, preferably incorporating elements from third and fourth generation engagement (see Table 3.2). Dialogue for community development should not have an explicit agenda other than to understand the needs and expectations of people. It should seek to establish trust and confidence in the process. Without this, development work has no basis to move forward. This first step of gaining understanding includes undertaking socio-economic baseline studies and social impact assessments, as discussed earlier.

### **Step 2: Working in collaboration**

Once concerns have been understood, community development work can become more collaborative; people are encouraged to work together to tackle issues that concern them. In this step, community development focuses on connecting people and building a sense of community cooperation. This is always going to be a challenging step as there are some community organisations, such as “Lock the Gate”, that are openly hostile to engaging with mining companies.

### **Step 3: Building partnerships and strengthening organisations**

The third step in development work is to help build partnerships between different groups and organisations so there is a sense of shared focus for achieving agreed outcomes. Organisational strengthening may be necessary, particularly where there is a lack of capacity for undertaking community development work at a local level. An example of this is the Flyers Creek Landcare Group established in part by Newcrest’s **Cadia Valley** Operations near Orange in NSW (see LP **Community** p.37).

### **Step 4: Broader connections**

The fourth step is about encouraging connections with people outside the community on similar issues. An example of this is where a mining company facilitates the sharing of information and experiences about effective Indigenous employment programs with Traditional Owner groups from another part of Australia. Another example is where links are facilitated with other organisations which have expertise and resources that they can share with the community.

## **Indigenous Communities**

### **Accessible recruitment processes**

Employment opportunities are usually at a peak during the development stage of a mining project. However, the recruitment process is a significant issue facing Aboriginal people. Affirmative selection strategies based on Equal Opportunity legislation are often required, with entry level jobs being reserved for local Aboriginal employees. Conventional HR practice involving newspaper advertisements and websites will not reach many Aboriginal candidates. Written letters of application, standard forms, resumes, standard psychometric testing and standard interview techniques are not suitable for Aboriginal people who are raised in a strong cultural context.

Good recruitment practices for Aboriginal candidates include:

- face-to-face communication at community level.
- the use of extended Aboriginal family networks to identify potential candidates.
- provision of assistance to prepare application forms.
- confidential medical advice.
- preliminary advice on the importance of occupational health and safety issues and zero tolerance policies in relation to alcohol and drug use at the mine site. The extent to which a potential employee appears receptive to these messages can be a valuable screening process when selecting potential employees.



The use of 'selection centre workshops' to recruit Indigenous employees has been particularly successful at a number of sites. Typically, this involves short-listed candidates attending a one-to-four-day residential workshop with other candidates. Company people participate in the workshop and observe candidates as they undertake classroom activities, practical outdoor and indoor exercises, site visits and social activities. The skills being assessed include how effectively an applicant can carry out practical tasks, solve problems, understand safety measures, work interpersonally, understand and take instruction, and work in a team cooperatively.

### **Recruitment and retention strategies**

Most Indigenous recruitment initiatives include work-readiness training, traineeships and apprenticeships but all need to incorporate life skills training and mentoring as major components. Life skills training:

- reinforces work habits of attendance and punctuality.
- helps trainees to manage family/work obligations.
- may include providing assistance with personal financial management.

Experience has shown that if Aboriginal employees can remain in employment for 12 months their long-term retention potential improves dramatically. Strategies to improve retention rates include:

- family support mechanisms.
- flexible work rosters.
- career development opportunities.
- addressing racism in the workplace.

Aboriginal customary obligations, such as attending frequent funerals, can usually be accommodated within normal workplace practices and policies, such as bereavement leave, holiday leave and leave without pay.

Successful Indigenous employment programs are comprehensive in scope and:

- require contractors to meet the same employment obligations as the client company.
- offer cadetships and vacation employment for tertiary-enrolled Indigenous students to encourage the development of Indigenous employees as technical specialists and managers.
- focus on employment strategies for Aboriginal women, who appear to adapt particularly successfully to the demands of the mining workplace.

An example of an Indigenous recruitment strategy is Barrick Gold's **Cowal** gold mine. The Cowal Gold Mine is located 47 kilometres north-east of West Wyalong in New South Wales. Barrick has entered into an agreement with a Native Title Party representing the Wiradjuri people. As part of this agreement, the Wiradjuri Condobolin Corporation (WCC) was formed. It is a group with which Barrick has worked in partnership on a number of projects. In partnership with the Condobolin TAFE, the Wiradjuri Condobolin Corporation and Barrick, an Introduction to Mining

course was designed to train and prepare Indigenous people who wished to apply for positions on mining sites. During the course, the students attended the Lake Cowal mine site to complete a guided tour and on-site inductions. This gave them a first-hand understanding of what would be required of them if they were to obtain employment on site (see LP **Indigenous** p.25).

At the completion of the first course the following results were achieved:

- 19 fully completed the course from 21 enrolments.
- eight graduates obtained employment with Barrick and construction companies on site.



Figure 3.3 - Cowal gold mine

## Monitoring

### Introduction

At the development stage of a greenfields 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 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 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.

### **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.

### **Monitoring for social performance over project stages**

As indicated in the Leading Practice Monitoring 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 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.

## Mine Rehabilitation Planning During Development and Construction

### Materials characterisation

Both waste materials and ore that are to be excavated can offer opportunities and risks for rehabilitation. Characterisation of topsoils and overburden should start as early as the exploration phase and continue through the pre-feasibility and feasibility phases as a basis for mine planning. Early characterisation of materials enables plans to be developed to avoid potential risks and to gain maximum benefit from material that may be particularly well-suited for construction for site infrastructure or for use in rehabilitation.

Characterisation of these materials should be undertaken to ensure that they do not have the potential to create an adverse impact or prevent successful revegetation being achieved during mining or at closure. The requirement for characterisation continues during the operation of the mine, particularly where the ore grade and mine plan change in response to altered market conditions.

Mine site structures such as run-of-mine (ROM) pads, haul roads or contractor lay-down areas should only be constructed using 'benign' materials. Where possible, these structures should be placed in already cleared areas to minimise the amount of rehabilitation required.

## Closure Planning During Development and Construction

It is essential that construction contractors and personnel understand the implications that their activities may have for the eventual closure of the mine. Mines can close during the commissioning and construction stage due, for example, to budget overruns. Therefore activities disturbing the site should be kept to a minimum during this phase. It is also important that local landowners and the local community are not unnecessarily inconvenienced at this time and that the foundations for long-term relationships are built. During this phase, planning and design decisions can have long-term consequences for the environment, future land uses, community health and safety that will impact upon the mine closure and completion process. For example:

- poor foundation construction for a tailings dam or water storage ponds can lead.
- to exacerbated long-term seepage and potential groundwater contamination.
- waste rock dumps designed to handle sulfidic waste need to have appropriate low.
- permeability foundations and/or acid consuming material placed as a basal layer.

- poor erosion controls during construction can result in increased sediment loads.
- to water courses during rainfall events.
- proper storage and handling of fuels and lubricants, and sound workshop.
- management can reduce long-term contamination from spillages.
- proper identification and handling of topsoils and other growth media, and.
- control of dusting from these stockpiles, can assist immediate and long-term.
- environmental management.

## Risk Management

Given the long-term implications of decisions made at the project development phase, it is vital that risk assessment workshops are held at key stages—usually at pre-feasibility, feasibility and project execution stages. The outcomes of these risk workshops should drive decisions on the future direction of the project.

The nature of mining can often present a range of uncertainties—on the extent of environmental impacts, social benefits, economic outcomes, geologic conditions and even political risks. Stakeholders will have different perceptions of uncertainty and the various aspects of mining. As noted in *Enduring Value*, implementing sustainable development principles requires mining professionals to consider the complexity of stakeholder relationships that may exist over the long term and at great distances. Uncertainty arises due to the complex inter-relationships between economic, environmental and social risks. This situation is illustrated in the case study: Risk Management of the **Ok Tedi** Project, Papua New Guinea. This one mine has probably been responsible for more anti-mining words, films and other media and legal action than any other mine in recent history. It has galvanised a generation against mining, particularly in developing countries, it has given impetus and momentum (and funding) to NGOs and environmental activists opposed to the mining industry and, built the reputation of one Australian law firm.

The Ok Tedi copper-gold deposit was discovered in the 1960s and subsequently developed by an international consortium led by BHP Ltd in the mid-1980s. The project is located in the Star Mountains of Western Papua New Guinea (PNG). The remote region has intense rainfall, steep and rugged mountains, is prone to landslides and is also within a seismically active area. The engineering challenges for mine waste and environmental management in this context are significant.

There are a multitude of risks which need to be considered with a project such as Ok Tedi. The extent and nature of environmental impacts present numerous and varied risks—during operation as well as during closure, and following rehabilitation. The social risks are difficult to assess—who receives benefits versus negative impacts, and are further complicated by the varying perceptions of the nature of social risks (within PNG and externally in the developed world). Initially the economic impacts and risks of the project may appear to be easy to ascertain and assess but the costs and externalities derived from environmental and social impacts can be very significant and impact on project economics.

Operating major mining projects presents an array of governance and government risks. For example, when governments are minority investors in projects (the receivers of royalties and taxes) as well as regulators, the perceived conflict of interest and need for transparency presents major challenges.

The Ok Tedi project and the dilemmas it raises are not unique in the world—the multi-faceted and interconnected nature of risk is at the heart of the sustainability debate. The mining industry can contribute to sustainable development by striving to understand the complex relationships between social, environmental, economic and governance risks.

The Ok Tedi case has helped to lift the awareness of these issues in the mining industry as well as the public realm along with the need to implement sound risk management for such large and complex projects and improve the global mining industry's approach to risks and sustainability (see LP **Risk** p.7).



Figure 3.4 - The Ok Tedi mine in Papua New Guinea

## Stewardship

Stewardship involves the care and management of a commodity through its life cycle. The idea of a life cycle can cover the exploration, mining, processing, refining, fabricating, use, recovery, recycling and disposal of a mineral product. Stewardship needs to be an integrated program of actions aimed at ensuring that all materials, processes, goods and services are managed throughout the life cycle in a socially and environmentally responsible manner.

Stewardship is an evolving concept within the mining industry aimed at building partnerships throughout the life cycle of materials to ensure the sustainability of their production, use and disposal. While participants in each sector have a



responsibility for stewardship in their specific industry, it is a fundamental principle of stewardship that those participants also have a concern in the other industries of the life cycle.

An example of stewardship opportunities to reduce sustainability impacts by acting during the development stage of an operation is provided by the Anglo Coal operations in the Queensland Bowen Basin. Removing the methane gas accumulations before mining, results in the elimination of both an explosion risk and a potent greenhouse gas. Furthermore the gas can be used directly in energy production. For example, Anglo Coal has entered into an agreement with Energy Developments Limited for construction of a gas-fired power project at its **Capcoal** mine.

This project will utilise methane drained from underground mining operations for on-site generation of electricity—sufficient to supply a small town. The 32 megawatt project, consisting of 16 reciprocating engines each with two megawatt output, is supported by a Commonwealth Government grant. The greenhouse gas mitigation effect of the power project at full capacity will be 1.2 million tonnes of carbon dioxide equivalent per year, including the effect of displacing the emissions from alternative fuels that would otherwise be used to generate the equivalent amount of electricity supplied to the state grid. That amount of mitigation is equivalent to planting 1.6 million trees or taking 250 000 cars off the roads.

Minimising waste, generating power and cutting back on greenhouse gas emissions is an excellent example of stewardship that benefits the environment and the bottom line (see LP **Stewardship** p.24).

## Planning, Design and Construction of Tailings Storage Facilities

### Introduction

The international mining industry has learnt many lessons over the last decade that have helped to develop leading practice tailings management in Australia. The International Commission on Large Dams (ICOLD) Bulletin 121 (2001) provided a comprehensive report of these lessons, drawing from a range of tailings storage facility failures and incidents. The main causes of failures and incidents identified were:

- lack of control of the water balance
- lack of control of construction
- a general lack of understanding of the features that control safe operations.

Conventional economic analysis can lead to minimising initial capital expenditure on tailings construction and deferring the costs of rehabilitation (see case study LP **Tailings**). Net present value analysis discounts the current cost of future expenditures on closure, rehabilitation and post-closure management. Therefore, if this short-term economic perspective is taken, without taking into account the longer-term social and environmental costs, there is little motivation to invest more substantially at the development stage to avoid or reduce expenditures at the closure stage. There is however a number of reasons for applying leading practice at

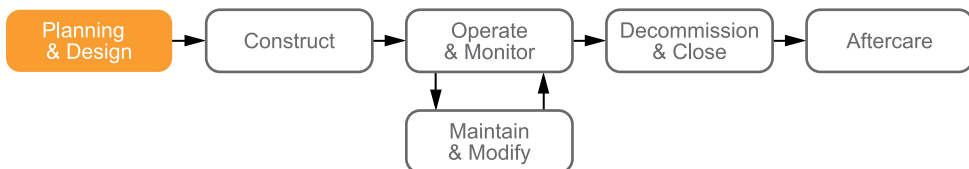
the earliest stage of development, and in designing and operating the tailings storage facility to optimise closure. Designing and operating for closure can avoid significant earthworks expenditures to re-establish stable landforms and drainage systems. Progressive rehabilitation, where possible during operations, enables rehabilitation work to be done while there is an operational cash flow, and management and resources available. Progressive rehabilitation can also reduce the cost of financial assurance required by regulatory agencies. Leading practice tailings management will also minimise the time required for post-closure monitoring and maintenance.

Good planning and design are the first steps in ensuring tailings are managed in accordance with the principles of sustainable development as shown below.

Leading practice requires alignment between the tailings storage facility planning and the mine plan. Tailings storage facility planning must also be reviewed in response to any changes to the mine plan, and revised, if necessary. This will ensure that any staging or sequential raising requirements are adequately financed and scheduled, and that operation and management activities strive to achieve closure objectives throughout the project life.

Consideration should be given to:

- integration with the mine plan and schedule in developing the tailings disposal methodology. For example, utilising or stockpiling topsoil and waste rock for construction of containment wall raises and/or caps and covers.
- location of the tailings storage facility to avoid sterilising mineral resources or contaminating water resources.
- availability of suitable embankment construction materials and surface capping materials.
- change management. For example, increases in processing plant throughput impact storage requirements for tailings and water, as well as the rate of rise of the tailings surface, can have implications for tailings strength and stability.
- reprocessing of tailings. Some tailings may contain valuable minerals and therefore a management objective may be to provide interim storage until economic recovery becomes feasible.



As construction proceeds, it is important that an accurate record of all works is kept in order to:

- ensure the tailings storage facility was constructed by a competent contractor, with an appropriate level of supervision and quality control of construction materials and techniques to show they were in accordance with the design drawings and specifications.
- provide a detailed record and description of geo-technically critical aspects such as the preparation of foundations, treatment of cracks in key and cut-off trenches, or the compaction of backfill around outlet works. This record assists in the design and construction of remedial works if any post-construction issues occur.
- provide as-constructed drawings that:
  - provide an accurate representation of the detailed construction works, particularly where design changes may have occurred during construction;
  - assist in improved designs for further stages;
  - provide details and dimensions for remedial works so that these do not impact the integrity of existing structures; and
  - provide details for back-analyses should these be required.

## Water Management

### Introduction

Mine management needs to take into account the following water considerations in resource development and design

- Water supply - identification and quantification.
- Impacts of water abstraction/diversion on local water resources/users.
- Government approvals.
- Water supply, storage and treatment (design and construction).
- Dust suppression and dewatering discharge.
- Waste water disposal.
- Site stormwater management.

It is essential that extensive investigations are carried out during the development stage to ensure water management is integrated into the overall management system of the mining operation. Clearly the mine will need sufficient water for the mining operation including dust suppression, equipment needs, washing, potable, sanitation etc. More significantly, given the considerable demand for water is in the processing stage. A rule of thumb for gold mining suggests that one tonne of ore processed requires one tonne of water. If a mine processes 2 million tonnes a year, which is not a large mill, then the water make required is very substantial. The Cadia Valley operations provide an example of managing the scarce water resource and balancing the mine's demands with competing demands from other users.

## Watercourse diversions

In order to access the mineral resource in surface mining operations, it is occasionally necessary in the development stage to divert a creek or river around the workings. Leading practice design of watercourse diversions will reduce time and cost associated with the approvals process. The main activities that must be undertaken to plan for and implement a diversion at various stages during the life cycle of an operation are shown in Figure 3.5.

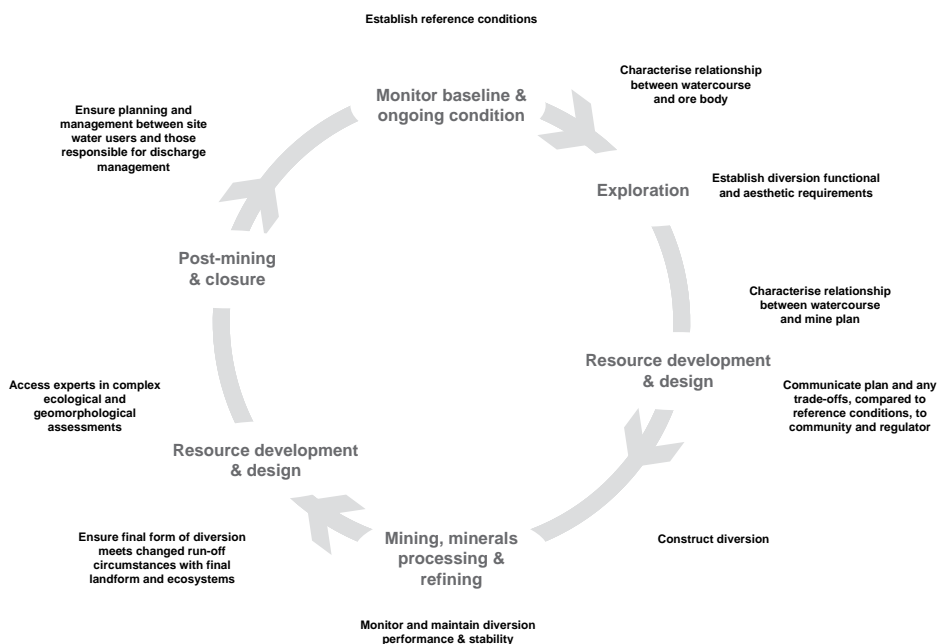


Figure 3.5 - Significant issues in designing and managing watercourse diversion across the life of an operation

**TRUenergy Yallourn** supplies 22 per cent of Victoria's electricity requirements. Its current coal supplies were expected to be exhausted in 2009, and nearby Maryvale Coalfield presented the best potential future coal supply. However, the Morwell River was located between the mine and this coal reserve. A river diversion was proposed that would lead to economic and environmental outcomes. A design team comprising mine planners, geotechnical experts, ecologists, embankment designers and hydraulic engineers was formed. It was agreed the diversion embankment could be constructed in engineered fill from 13 million cubic metres of overburden that needed to be stripped from the mine, significantly reducing the cost of the project. The design required the creation of a 70 metre wide and a 3.5 kilometre long diversion channel on top of an embankment that commenced at the Morwell River upstream, and connected with the Latrobe River downstream. The channel design accommodated a 1 in 10 000 year probability flood and was designed to mimic the geomorphic and ecological characteristics of the natural Morwell River (see LP **Water** p.71).

The Morwell River Diversion project guarantees the life of TRUenergy Yallourn's mine for at least 30 more years by providing short and long-term accessibility to critical coal reserves thereby ensuring continued supply of a major portion of the Victorian and national electricity supply. The following economic, social and environmental outcomes were achieved:

- Works on the diversion provided more than 150 construction jobs over the period 2001 to 2005 inclusive.
- Without the diversion, the cost of electricity generation would have significantly increased.
- Under the Native Title Agreement established, a number of local Aboriginal elders were engaged as cultural observers.
- The diversion has delivered significant environmental improvements, compared with the original design, including retaining two kilometres of original river flood plain and ephemeral wetlands.



Figure 3.6 - Construction of the Morwell River diversion



Figure 3.7 - Morwell River after diversion

Diversions are similar to drainage structures in that their functional aim is to route flow around and away from the operation in a safe, predictable and efficient manner. Natural watercourses are dynamic (prone to flooding and channel instability), whereas diversions must be stable, contain flows and not affect flood levels to an unacceptable degree. The diversion must also not act as a physical barrier to the migration of aquatic organisms. Operational diversions are, therefore, a trade-off between environmental requirements (values, processes and variability) and certainty in hydraulic and geo-mechanical performance. Economic considerations provide some constraints on the extent to which environmental conditions can be realised compared with theoretical outcomes.

## 4.0 MINING & PROCESSING OPERATIONS



Figure 4.1 - An example of sustainability impacts of a mining operation - breakthrough of the Ridgeway sublevel cave - Orange, NSW, Australia

### Key Messages

- the operations phase is the most challenging as far as sustainability is concerned as mines can have longevities of 50 or more years
- planning decisions for sustainability made in the development phases impact either positively or negatively in the operations phase
- systems need to be developed and reviewed throughout the mine life particularly environmental management systems and community engagement initiatives
- risk management techniques are essential in managing sustainability impacts during operations
- a focus on materials stewardship particularly in the waste stream will pay sustainable dividends
- companies are increasingly including the local community in managing the impact on biodiversity
- water management continues to be a major issue for mine management and eliminating the acid mine drainage risk is at the forefront of research

- tailings disposal techniques continue to evolve such as in in-pit or thickened discharge methods
- the safe storage and handling of cyanide and other hazardous substances is now well established with much guidance material available for mine management.

## Introduction

Mining operations in Australia and internationally cover a range of commodities, sizes, and methodologies. The Australian minerals sector is in the top five producers of most of the world's key minerals commodities including

- The world's leading producer of bauxite, alumina, rutile, and tantalum.
- The second largest producer of lead, ilmenite, zircon and lithium.
- The third largest producer of iron ore, uranium, and zinc.
- The fourth largest producer of black coal, gold, manganese and nickel.
- The fifth largest producer of aluminium, brown coal, diamonds, silver and copper (MCA).

Australian mining methods range from surface mining that may include strip mining with draglines; truck and shovel or conventional open pits; and alluvial or placer mining, including dredging for mineral sands, precious metals and gems. Underground coal mining ranges from longwall and bord and pillar while caving and stoping methods are most common in hard rock mining. Apart from "mining", this chapter will also highlight sustainability issues associated with mineral processing, metallurgical operations and occasionally refinery operations.

Each of these methods may result in significant potential impacts on the sustainability of mining operations and thus each operation demands the highest level of management skills to minimise any negative impacts. This Chapter covers leading practice in sustainability during the production or operations stage of the mining cycle. It is during this phase that the benefits or costs of the planning decisions implemented during the earlier phases are realised. This is also the phase of mining where the greatest potential impacts on the environment and the community occur.

## Airborne Contaminants, Noise and Vibration

A recent newspaper article (Safe, 2009) highlighted the issue of noise and its impacts, both real and perceived on the local community. The article detailed the recent formation of an anti-noise lobby group - Noise Watch Australia. One featured case involved a retiree who moved to a heavily timbered block some distance from a capital city. A sawmill increased its production to 24 hours, 7 days a week. In his words, "*the noise drove us darn crazy*" and consequently he sold up. Another complainant stated "*the growth of noise in communities across Australia is still not recognized for what it is - another form of pollution that's having serious health impacts on many people*". The World Health Organisation was quoted in the article as saying that up to three per cent of heart disease deaths, or more than 200,000 globally, are due to long time exposure to chronic traffic noise.



But are noise levels increasing? The EPA Victoria (EPA, 2007) indicates that noise across Melbourne hasn't increased since the 1970s and yet community complaints have risen considerably. In Britain, noise complaints are five times higher than they were 20 years ago. It is clear therefore that the community is becoming less tolerant to noise than it once was.

The issue of dust emanating from a mine site has been the focus of intense media scrutiny in Western Australia recently. The issue surrounds the export of lead concentrate from Magellan Metals' Wiluna mine from the ports of Esperance and Fremantle. The extent of community dissatisfaction can be seen from newspaper headlines in November 2008 (Clarke, 2008) - *"Unions promise to fight Barnett over lead shipments"* and *"Port's mayor vows to fight risky lead exports"* and *"Lead leaches hope of Esperance future"*.

These issues are important in all sectors of our industry - coal, metalliferous and the quarry sector. Indeed, the front cover of "Quarry", the official Journal of the Institute of Quarrying Australia in November 2007 headlined *"Ensuring your neighbours don't eat dust"*. The issues are important whether the mine is situated in the Tanami Desert, the Hunter Valley or a more densely populated area. It is often in the latter situation where most problems arise. In Australia, these situations are typical of quarries for construction materials; mines with a residential workforce such as Kalgoorlie, Mt Isa or Broken Hill or mining fields in locations such as the Hunter Valley where mining is often not considered the most desirable land use. Of course many Australian mining companies operate internationally and it is in these countries, where far higher densities of populations exist in the vicinity of the mines, that the community impacts of airborne particulates, noise and vibration are exacerbated.

The issue of air blast overpressure has to be well managed if mines are in close proximity to residential areas. Blast overpressure levels experienced from operations on open cut mines depend on many factors including the design of the blast, the distance from the blast to the receiver and the prevailing atmospheric conditions. The way in which temperature and wind vary along the path through which the over pressure wave travels from the source to the receiver is particularly important in determining the overpressure experienced at the receiver. Modelling allows the effects of atmospheric conditions to be taken into account before making the decision to blast and ultimately used to predict the enhancement of blast overpressure levels. The results are presented as contour plots overlaid on a map of the area surrounding the blast. An example showing blast overpressure enhancement is provided in the figure below. The results are promising and the system appears to be a useful tool, in its current state of development, to improve the management of impacts from blasting (see LP **ANCV** p.52).

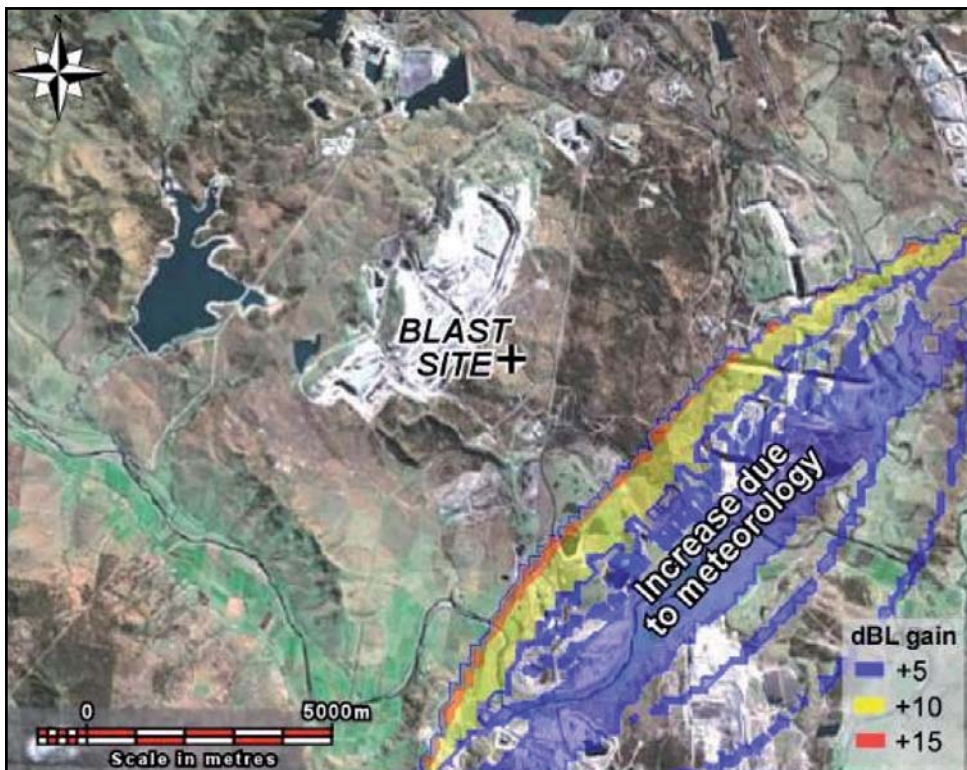


Figure 4.2 - Predicted blast overpressure levels showing zone of re-enforcement due to atmospheric conditions

## Biodiversity

### The Business Case for Managing Biodiversity

The risks and impacts to business of the failure to adequately manage biodiversity issues can include: increased regulation and liability to prosecution increased rehabilitation, remediation and closure costs, social risks and pressure from surrounding communities, civil society and shareholders; restricted access to raw materials (including access to land, both at the initial stages of project development and for ongoing exploration to extend the lifetime of existing projects) restricted access to finance and insurance. In some instances the sensitivity of the environmental and cultural values associated with particular elements of biodiversity may result in the exclusion of exploration and mining activities.

In recent years, some projects have undertaken an initial desktop review and reconnaissance of potential biodiversity issues in exploration and mining lease areas. This information can be used for defining the risk of investment and the potential for a 'fatal flaw' in the environmental impact processes, thereby reducing the social, economic and environmental risks. This also enables informed decisions to be made on the likelihood of a project progressing beyond the pre-feasibility stage, with a consequent saving on time and resources where progress is unlikely.

Conversely, positive and proactive biodiversity management can offer opportunities and benefits including:

- shorter and less contentious permitting cycles, as a result of better relationships with regulatory agencies.
- reduced risks and liabilities.
- improved community and NGO relations and partnerships.
- improved employee loyalty and motivation.

For these reasons, the minerals industry is increasingly adopting measures to conserve and sustainably manage natural resources. Gaining the support of international institutions such as the International Finance Corporation, World Bank and private financial organisations is now conditional on complying with internationally-recognised biodiversity principles and standards such as the Equator Principles voluntary social and environmental standards. Leading financial lenders and export credit agencies are increasingly integrating assessments of biodiversity impacts into their mainstream financial decisions. These financial institutions see environmental assessment as a key element of the overall risk management process. Increasingly, a mining company's ability to achieve high standards of biodiversity management is recognised as a competitive advantage. As a result companies that develop sophisticated policies and practices for managing biodiversity enjoy greater opportunity, particularly with respect to land access.

### **Maintaining the Social Licence to Operate**

Mining activities often occur in remote environments where local communities engage in subsistence agricultural practices or sustainable livelihoods based on surrounding natural resources. In these circumstances, the human (social and economic) dimensions of biodiversity take on critical importance. This is particularly true in the rural areas of developing countries, where entire communities are directly dependent on biodiversity and ecosystem services and therefore more vulnerable to their degradation.

Public concern over biodiversity loss and ecosystem damage is reflected in a growing number of initiatives. These range from civil society and local community action to international, national and local laws, policies and regulations aimed at protecting, conserving or restoring ecosystems. To maintain their social licence to operate, mining companies are responding to expectations and pressures for stricter measures to conserve and manage remaining biodiversity. They are increasingly being called upon to:

- make 'no go' decisions on the basis of biodiversity values, which may include pristine, sensitive or scientifically important areas, the presence of rare or threatened species, or where activities pose unacceptable risks to ecological services relied upon by surrounding populations (see Shelburne Bay case study).
- alter the project development cycle where there is insufficient baseline information or where scientific uncertainty mandates a precautionary approach in relation to mitigating or avoiding impacts on biodiversity; and, where practicable, mitigate impacts and positively enhance biodiversity outcomes in areas where they currently operate.

Responsible management of biodiversity, in conjunction with key stakeholder groups such as regulators and indigenous peoples, is a key element of leading practice sustainable development in the mining industry. Engagement with these groups is discussed further in the *Leading Practice Handbooks on Community Engagement and Development* and *Working with Indigenous Communities*.

An example of this leading practice approach in community partnerships is at Tiwest's **Cooljarloo** heavy mineral mine site in WA (see LP **Biodiversity** p.6). Tiwest's philosophy of adding value in partnership is apparent in biodiversity partnerships with the Perth Zoo, Department of Environment and Conservation and local schools. Joint work with the Department of Conservation and Land Management's (CALM) Western Shield program has seen regional fox numbers reduced to the point where there have been successful releases of woylies, Tammar Wallabies and Quenda into nearby Nambung National Park. The Cooljarloo operation is based on an approach to sustainable development that incorporates a broad range of leading practice approaches, including:

- the collection of seed from mature plants before disturbance.
- materials segregation (topsoil, clay overburden, processed material) that contributes to the rehabilitation and the establishment of landforms, particularly the management of fine clay slurries or 'slimes'.
- supporting the re-colonisation of locally extinct faunal species within nearby national parks.
- partnerships with local indigenous business enterprises for seed collection and other services. For example, Tiwest's partnership with Billinue Aboriginal Community is now in its 12th year with over a million dollars worth of local provenance seed collected and 700 ha of disturbed land revegetated.
- ongoing partnerships with a wide cross-section of the local community covering educational projects, environmental management and support for community organisations.

### **Managing impacts on terrestrial vegetation and fauna**

The first step to minimising direct impacts on vegetation and associated faunal communities is to identify the location of values from survey information. From this environmental management plans can be developed and implemented to ensure that, where possible, high value areas are not cleared. In all instances, these plans should ensure that the extent of clearing is minimised, consistent with the safe and efficient operation of the mine. The extent of suitable habitat and its connectivity should allow for the mobility of most fauna species. Successional aspects are also important. For example, inappropriate fire regimes can affect all of a remnant area within a mining lease resulting in the loss of certain species. Rapid rehabilitation of disturbed areas can minimise the impacts of habitat fragmentation.

Even in instances where rare or threatened fauna species are no longer present in an area, if surveys show the habitat to be either formerly occupied by the species, or suitable, then it should be managed accordingly, since it is possible that the species may colonise (when threatening process such as fox predation are removed or reduced), or be reintroduced at some later stage.

Secondary impacts such as changes in grazing patterns and the introduction or increases in weeds and feral fauna should be addressed by the development and implementation of land management plans. Identification and control of problem weeds, including the prevention of introduction in and adjacent to operating areas, should be carried out. Where feral fauna such as the fox, cat, pig or goat are negatively impacting conservation values, their numbers should be monitored and if necessary, control methods implemented.

Leading practice biodiversity management goes beyond minimising long-term impacts from operations. It identifies opportunities for improvement in the lease and adjacent areas by introducing innovative and sustainable land management practices and/or controlling weeds and feral fauna to the greatest practicable extent. These initiatives may be undertaken by the companies themselves, or in partnership with government and NGOs.

### **Managing impacts on aquatic fauna**

Aquatic ecosystems occupy low-lying parts of the landscape and will, therefore, be the ultimate recipients of runoff from mining activities. The linkages between the quality of terrestrial ecosystem management and receiving aquatic ecosystems are typically very strong. It is therefore difficult to achieve good outcomes from planning management of aquatic ecosystems without due consideration of these linkages.

Mining impacts on aquatic ecosystems arise from four sources:

- water quantity issues
- water quality issues
- habitat structure issues and
- organism passage issues.

Alterations of the surface runoff and/or groundwater flow characteristics and pathways can affect water quantity. Mined landscapes can differ greatly in rainfall-runoff relationships from the original landscape. Rehabilitated landscapes will commonly have altered topography from the original landform, resulting in changes to the directions, quantities and timing of surface flows.

Furthermore, mines often intercept or use aquifers. The geological layers mined may themselves be important aquifers supporting groundwater dependent ecosystems. In the arid and semi-arid regions that host much of the Australian mining industry, ground waters are commonly key resources used by mining companies. The impacts on these ecosystems during and post operation need to be understood as do mechanisms for their maintenance and rehabilitation.

The ANZECC/ARMCANZ (2000) Water Quality Guidelines summarised in Batley et al. (2003) together with associated state and territory legislation, constitute a water quality risk-management framework for management of biodiversity in aquatic ecosystems. Leading practice management of water quality impacts follows the risk-management framework of the guidelines. It should also ensure the monitoring program sensitivity can detect trends in water quality parameters while the measurements remain below the water quality objectives. This allows management steps to be implemented before a declining trend of water quality can lead to biodiversity impacts.

Leading practice management of water quality should also include management and monitoring of process reagents, solid and liquid wastes (including domestic wastes), hydrocarbons, degreasers and sewage effluents. These aspects can be particularly important during periods of high rainfall, when it may be difficult to retain all surface and groundwater runoff from mining-related infrastructure, including contractor sites.

The water quality guidelines do not fully address the difficulties associated with their application to temporary waters. In particular, the trigger values contained in the guidelines are based on steady-state conditions that by definition do not occur in temporary waters; there are no toxicity-based trigger values provided for inland salt lakes; and the recommended biological water quality assessment strategies are untested for mining impacts in all but a few types of temporary waters. This limits their use in the arid and semi-arid zones of Australia, where temporary waters dominate, and where the majority of mining occurs.

Habitat structure in aquatic ecosystems is a major controlling factor of biodiversity. Sedimentation of stream beds, pools and backwaters can result in reduced biodiversity due to the reduction in the available niches. Stream diversions that do not match the pre-existing habitat structural diversity will be unlikely to support the original aquatic biodiversity. This may affect biodiversity upstream and downstream of the diversion by alteration of organism passage and reach-scale ecosystem energy flow. Leading practice managers design compensatory habitat structures into the diversion, such as planting additional overhanging reeds, rushes and shrubs and constructing natural or above natural densities of large woody debris structures. The engineering design of the diversion should account for the increased hydraulic roughness associated with these structures.

Alteration of the landscape caused by mining that results in altered flow paths and velocities of surface and ground waters will result in altered geomorphic influence on the receiving aquatic ecosystems. The resultant impacts on aquatic habitat structure and the biodiversity dependent upon it need to be considered.

## The Community and Mining Operations

### The Business Case for Community Engagement

Engaging with communities and contributing towards community development is not only the right thing for companies to do, it also makes sound business sense. First and foremost, companies need to secure broad community support and acceptance in order to protect their 'social licence to operate'.

Companies that are perceived as closed and non-responsive will be much less likely to have the trust and support of a community than those which share information openly, listen and respond to people's concerns, and show that they care about the community and are committed to its development. By listening and engaging, companies will also be better placed to identify emerging community issues at an early stage and deal with them proactively rather than reactively. Consequently, these companies will also have a greater opportunity to put their views to the community, and having those views heard.

The time taken to plan, finance, insure and regulate any operation has increased substantially in the past few decades, particularly in the case of large-scale mines. In these circumstances, there can be real financial returns for those companies that

are able to show that they take their community responsibilities seriously (Harvey & Brereton, 2005). These benefits can include reduced time in obtaining approvals and negotiating agreements, easier access to new resources, an improved corporate risk profile and, potentially, the ability to secure access to capital on more favourable terms.

For those companies with residentially-based operations in relatively remote parts of Australia, another business driver is the challenge of attracting and retaining employees, particularly in the context of recurring skills shortages. Put simply, employees and their families will be more likely to move to, and stay in, communities if they are seen as offering a good quality of life with long-term educational, recreational and employment opportunities, for young people in particular.

This provides a strong incentive for companies to invest time and resources in contributing to the development of these communities.

### **Indigenous Communities**

With more than 60 per cent of Australian minerals operations neighbouring Indigenous communities, the development and maintenance of strong and positive relationships with Indigenous communities is critical to securing and maintaining the industry's social licence to operate. Increasingly, agreements with Traditional Owners require mining companies to engage effectively with Indigenous communities and contribute to long-term development objectives. Companies that are unable or unwilling to do so, or fail to follow through on undertakings, are likely to be seriously disadvantaged when it comes to negotiating future agreements with Traditional Owner groups.

As well as the broader corporate business case for the establishment of lasting relationships with Indigenous communities set out above, there are a number of specific benefits to mining companies from such relationships. They include:

- facilitating the development of mutually beneficial and sustainable land access agreements. Such agreements respect Indigenous rights and interests in country as well as securing access for exploration and mining, and are achieved through negotiation based on respect and common understanding, rather than litigation.
- facilitating legal compliance through the protection of Indigenous cultural heritage.
- accessing a local labour force based in neighbouring Indigenous communities that could decrease dependence on expensive fly-in, fly-out operations and/or reduce the need to establish mining towns.
- attaining the benefits of workforce diversity through increased Indigenous employment.
- securing a local supply chain through local Indigenous-owned businesses
- gaining input from Indigenous community members in various aspects of a mining operation, such as environmental management, risk management, mine closure planning and the management of social impacts.
- ensuring better outcomes in environmental management through access to local and traditional ecological knowledge.
- enhancing the industry's sustainable development credentials by contributing to the development of prosperous and sustainable regional communities.

Barrick's Pierina mine operates in an area dominated by Indigenous people in the Andean mountains of Peru. The following case study highlights the positive influence that mining can have on a community in which a modern mining operation is located.

**MINE:** Pierina Mine

**LOCATION:** District of Independencia and Jangas, Province of Huaraz, ANCASH, PERU, SOUTH AMERICA (pop. 67000).

**BRIEF DESCRIPTION:** The Pierina mine is located in the Andean Cordillera in the Department of Ancash in north-central Peru, approximately 10 kilometres northwest of the city of Huaraz, at an altitude of approximately 4,100 metres. The most important areas of influence are the districts of Independencia and Huaraz.

Pierina is an open-pit mine of gold (period of operation 1996 - 2010), truck-and-loader operation. Ore is crushed and transported through an overland conveyor to the leach pad area. Run-of-mine ore is trucked directly to a classic valley-fill type of leach pad.

In 2009, Pierina produced 271,000 ounces of gold at total cash costs of \$400 per ounce. Proven and probable mineral reserves as of December 31, 2009 are estimated at 648,000 ounces of gold<sup>2</sup>. Accumulated investment: US\$ 850 million.

**AREA OF LEADING PRACTICE:** Poverty reduction; human development

**HANDBOOK(S) REFERENCE:** Community Engagement

**DESCRIPTION OF CASE OF STUDY:**

Peru is a significant mining country. Over the past two decades some Peruvian mining regions have experienced important social and economic transformations, particularly in comparison to non-mining regions. This analysis seeks to evaluate the contribution made by mining development to economic and social progress in the districts of Jangas and Independencia.

Pierina Mine, operated by Barrick, has a complete program of community development. From the first day of operation the policies of the Company had been to ensuring that the benefits of mining are shared with communities. In collaboration with their partners, Pierina Mine had been supporting the improvement of access to clean water, health care, housing and education for people in the communities in which it operates. In this manner the company contributes positively to competitiveness, linkages, creates a stable business environment, retains a skilled base of employees and provides essential services to community.

This case study illustrates the key indicators of poverty reduction within the districts of Independencia and Jangas (area of influence). These indicators are the best manner to illustrate the impact of various policies, operational activities, taxes, donations, and the new capacities and the new social capital of the community in the area of influence, and the positive relationship between the mining operation and the community.



The area of influence of Pierina Mine shows changes considerably different to its immediate surroundings (Huaraz Province, ANCASH and Peru), and the changes were produced in the same period of operations of Pierina.

For this reason is possible to state that there is a positive relationship between the positive changes and Pierina mine activities. Of course, all changes and social progress will depend on people and their groups of belonging, out of all, Pierina provides a better scenario.

### **Analysis of Indicators**

The rate of demographic growth in the area of influence, between 1993 and 2007, shows an average of 31.1% of growth, versus 11.4% in Ancash and 24.3% in Peru at the same period. In the same way, the poverty reduction in the area of influence had experienced a dramatic fall. In Jangas the poverty fell from 80% (in 1993) to 31.3% (2007) and in Independencia from 57.4% to 30.7%. These results are better than the poverty reduction of Peru and Ancash (in the same period) that remained above 40%. This socioeconomic scenario for the area of influence is highly positive compared with the rest of Peru, because only selected regions can shows poverty indicators under 33%.



Figure 4.3 - Location map of Pierina mine

\*Contributed by Christian Para

### **Weipa - a sustainable approach to the community**

The approach and content of a mining operation's contribution to community development should be determined by local conditions such as the nature and scale of the operation, available government resources and local people's specific needs and priorities. Mining companies should work in support of local community priorities and existing programs rather than having predetermined projects or approaches to offer local communities. Full and active engagement as described earlier in this handbook is, therefore, essential for sustainable community development. As an example, the Comalco's **Weipa** bauxite mine has been operational for 50 years, with mining expected to continue for at least another 50 years. Management engaged both Indigenous and non-Indigenous community groups of the Western Cape York Peninsula of Queensland, in sustainability planning for the region (see LP **Community** p.30).

Outcomes that have been achieved since the start of the process include:

- a partnership between Comalco, Queensland Health and the local community which has enabled redevelopment of the old Weipa hospital into a new regional health facility and precinct—this project is due for completion in 2007.
- a memorandum of understanding and action plan for 2006 regarding Indigenous training and employment in the mining industry through a regional partnerships agreement which involves Comalco, federal and state government agencies, and local service providers.
- the participation by Comalco and other local employers in the Western Cape College Education Forum to increase alignment between educational outcomes and employment opportunities in the region.
- initiatives to improve social harmony in and around Weipa, including a revision of the cross cultural training package, and development of an induction program for new Comalco employees and their families.



Figure 4.4 - Bauxite mining and processing at Weipa

## Cyanide

### Introduction

Cyanide is a useful industrial chemical and its key role in the mining industry is to extract gold. Worldwide, mining uses about 13 percent of the total production of manufactured hydrogen cyanide while the remaining 87 percent is used in many other industrial processes, apart from mining (Environment Australia 1998). In Australia the mining industry uses about 80 percent of cyanide produced by the country's two cyanide producers. Cyanide is manufactured and distributed to the gold mining industry in a variety of forms. Sodium cyanide is supplied as either briquettes or liquid, while calcium cyanide is supplied in flake form and also in liquid form. Calcium cyanide, if used, may contain some carbide from its manufacture and present a risk of explosion from acetylene generation.

The hazard of cyanide derives from its property as a fast acting poison. Cyanide binds to key iron-containing enzymes required for cells to use oxygen and as a result tissues are unable to take up oxygen from the blood (Ballantyne 1987; Richardson 1992). In the absence of first aid, intake of toxic amounts of cyanide from gas inhalation, or ingestion or absorption through the skin, can kill within minutes. Low levels of cyanide from the consumption of foods are removed from the body by the liver. Cyanide is not carcinogenic and people who suffer non-fatal poisoning usually recover fully. However, chronic sub-lethal exposure above the toxic threshold, or repeated low doses, may cause significant irreversible adverse effects on the central nervous system and onset of Parkinson's syndrome.

Since its first use in mining in New Zealand in 1887, sodium cyanide has played a key role in extracting gold and other metals such as silver, copper and zinc from ores worldwide. Indeed about 80 percent of the world's gold production utilises cyanide in extraction, with about 2500 tonnes of gold being produced annually worldwide.

Despite its high human toxicity, there have been no documented accidental human deaths due to cyanide poisoning in the Australian and North American mining industries over the past 100 years which indicates that the hazard of cyanide to humans has been controlled by minimising the risk of its handling and of industrial exposure. One significant breakthrough has been the adoption of the International Cyanide Management Code.

### **Adopting the International Cyanide Management Code**

An expectation of Code signatories is to design, construct, operate and decommission their facilities consistent with the Code requirements. Their operations must be audited by an independent third party auditor and the results made public. The principles and standards of the Code must be implemented within three years of signing in order to receive certification. Independent auditing to demonstrate compliance with the Code is a prerequisite to certification. Comprehensive notes providing guidance on how the principles and standards of practice may be implemented are available at [www.cyanidecode.org](http://www.cyanidecode.org). Information on certified operators is posted on the web site of the International Cyanide Management Institute. In order to maintain certification, an operation must meet all the following conditions:

- full compliance or substantial compliance as indicated by the independent auditor.
- operations in substantial compliance have submitted action plans to correct deficiencies and implement these within the agreed timeframe (maximum one year).
- there must be no evidence that the operation is not in compliance with Code conditions.
- a verification audit is held within three years.
- a verification audit is held within two years of change in ownership of the operation.

The main impediments to industry's adoption of the Code are currently the burden of compliance, the complexity of implementation guidelines, adequacy and independence of ownership and administration of the code scheme via the International Cyanide Management Institute (Den Dryver 2002). See also case study on Code certification of Cowal gold mine below. The Cowal gold mine has attracted a minority of opponents to the development and continued operation of the site. It was identified in 2005 during the construction of the mine that compliance with Code was critical to core business and to maintaining broad community support. With strong support from the site General Manager, and department managers and a technical expert, a Cyanide Code Team was established with input from all areas including environment and safety; processing technical services, operations and maintenance; community relations and project construction. For further information on how Cowal achieved compliance with the Code see (LP **Cyanide** p.22).

### **The Business Case for Leading Practice in Cyanide Management**

Mining companies that adopt the International Cyanide Code and adhere to associated leading practice principles recognise that these principles also make good business sense. Leading practice mining companies develop and implement management and operating practices for the use of cyanide in mining activities that assist achieving sustainable development. The following may be derived from this initiative:

- improved protection of wildlife.
- improved relations with both the public and regulatory agencies.
- improved economic and environmental performance.
- reduced risks and liabilities.
- improved access to capital and potentially lower insurance costs.

In spite of the increasing level of knowledge about cyanide and its proper management in mining, significant environmental incidents—some involving water bodies—have continued to occur globally (Donato et al. 2007). These incidents attract concern from regulators and the public, and have led to calls for cyanide use in mining to be banned. A list of major cyanide incidents is provided in Box 1. In Australia, most spills of cyanide have occurred during transport to mine sites. An example of how one mine manages the environmental risk of cyanide in its tailings storage facilities is provided by Sunrise Dam in Western Australia. The **AngloGold Ashanti Sunrise Dam** gold mine (SDGM) operation is located 55 kilometres south of Laverton, Western Australia. The mine is situated immediately to the east of the hyper saline Lake Carey and is surrounded by numerous other smaller saline lakes. The operation is comprised of an open pit and underground mining operations as well as processing operations.

The tailings dam is currently a 320 hectare, single-cell CTD facility (central discharge system). Under normal operational conditions the thickened tailings are deposited at approximately 65 percent solids and there is minimal or no supernatant liquor or associated ponding from tails discharge. The central discharge system essentially results in conical stacking of dry tails. A stock and wildlife-proof electric fence has been erected around the perimeter of the structure. Unique to this broader region the processing solutions and tailings are hyper saline, about 190 000 TDS or six times more saline than seawater.

Monitoring of waste stream solutions revealed that the concentrations of weak acid dissociable (WAD) cyanide in the tailings dam were in excess of 50 milligrams per litre WAD cyanide on 72 percent of sampled days. WAD cyanide concentrations of supernatant pooling at times exceeded 50 milligrams per litre. The protective mechanisms of reducing cyanide-bearing habitats (by management and tailings system design), lack of food provisions, minimal water and hyper-salinity have resulted in no observed effect on wildlife. It was hypothesised that these mechanisms provide protective measures by eliminating and reducing the wildlife exposure pathways to those solutions (see LP **Cyanide** p.11).



Figure 4.5 - Sunrise Dam TSF

## Box 1: Major recent incidents involving cyanide

1. In May 1998 loss of 1800 kilograms of sodium cyanide to the Barskaun River, Kyrgyzstan, followed a truck accident en route to the Kumtor mine (Hynes et al. 1999).
2. In 1995 thousands of migratory and non-migratory waterbirds were killed at the tailings dam of the Northparkes mine, NSW, Australia, due to a poor understanding of the significance of cyanide chemistry and inappropriate analytical procedures (Environment Australia 2003).
3. In 2000 the tailings impoundment at Baia Mare, Romania, was breached, releasing a cyanide plume which travelled for 2000 kilometres downstream, killing very large numbers of fish in the Tisza and Danube rivers, and disrupting the water supply (UNEP/OCHA 2000) (Environment Australia 2003). Excessive treatment of cyanide with hypochlorite and chlorine exacerbated the problem.
4. A pallet of dry cyanide product, which fell from a helicopter en route to the Tolukuma gold mine in Papua New Guinea in 2000, was successfully cleaned up (Noller & Saulep 2004).
5. Cyanide solution from an incompletely discharged ISO-tainer was allegedly released on the roadside after a delivery truck left a mine in the Northern Territory in 2002.
6. Due to confusion over the number of valves in the cyanide plant at the San Andres mine, Honduras, 1200 litres of cyanide solution was discharged into the Lara River in January 2002.
7. Water contaminated with cyanide entered the Asuman River from the Tarkwa gold mine in the Wassa West District of Ghana in October 2001, killing fish and disrupting local water supplies. Another discharge into the river from a ventilation shaft in January 2003 rekindled community health and safety concerns, although this water was later shown to be potable.
8. In February 2007, a road train carrying three 20-tonne containers of solid sodium cyanide in the Northern Territory tipped over, spilling pellets onto the side of the road and into a non-flowing watercourse. Most spilled product was collected, and contaminated water and soil were cleaned up and disposed of at a nearby mine site.

A number of gold mines use cyanide destruction techniques in order to reduce the risk of environmental impact in tailings deposition. The Granites lease is about 550 kilometres north-west of Alice Springs and is owned and operated by Newmont Tanami Operations (NTO). It has been operating since the mid 1980s. The mine initially placed tailings in conventional paddock tailings storage facilities (TSF) and later expanded this practice to in-pit tailings disposal. In-pit tailings disposal has the advantage of storing tailings in a safe repository; filling a void that would otherwise remain open; and reduce the potential for wildlife mortalities especially birds.

For in-pit tailings deposition, tailings slurry is pumped and discharged into one of a number of mined out pit voids. Process water is recovered from pits and reused through the process circuit. The tailings slurry is pumped at 60 percent solids and contains 130 milligrams per litre WAD cyanide at the process plant. Without adequate controls, the WAD cyanide levels may pose risks to wildlife and groundwater quality. The Tanami region sits within the east Asian-Australasian flyway for migratory shorebirds. Daily bird checks conducted on the Granites lease since early 2005 have detected 12 of the 43 species listed in the 1993 National Plan for Shorebird Conservation in Australia. A further three species are likely to be found in the area during migration but have not been sighted on the lease. The Newmont Standard for Tailings Management states that tailings activities will not impact on groundwater.

There are potential environmental impacts associated with in pit tailings deposition in the Tanami including fauna mortalities associated with cyanosis and groundwater contamination. The water surrounding Bunkers Hill pit has been found to range from brackish to saline. The deposition of tailings into Bunkers Hill pit will probably result in a saline plume infiltrating the surrounding bedrock and being detectable for up to 250 metres from the pit. Tailing into Bunkers pit commenced in June 2007 and to date, groundwater contamination has only been detected in one seepage interception bore. As yet there is no evidence of connectivity between the surrounding groundwater and the pit in the other seepage interception or monitoring bores. This may change as the tailings rises in the pit, therefore, the bores are routinely monitored (see LP **Cyanide** p.60).

It is believed that the potential impacts can be managed by implementing cyanide destruction technology, installing a seepage interception system, and with diligent operational management and monitoring.



Figure 4.6 - Inpit tailings disposal at the Tanami

An international example of leading practice in a range of areas including cyanide, tailings disposal and general environmental management is the Chatree gold mine in Thailand which is ranked as the safest mine in the world, a remarkable achievement for a mine in an emerging economic region.

**MINE:** Chatree gold mine

**LOCATION:** Pichit, Thailand

**BRIEF DESCRIPTION:** Open pit gold mines

**AREA OF LEADING PRACTICE:** Safety; community engagement; international company operating in a developing country

**HANDBOOK(S) REFERENCE:** Community Engagement

**DESCRIPTION OF INNOVATION:**

The Chatree mine is the largest gold mine in Thailand. The mine is operated by Akara mining, a Thai subsidiary of Kingsgate Consolidated Limited, an Australian company. The mine provides an excellent example of how foreign-owned companies can work optimally in developing countries. Highlights include:

- 99% of the 1000-strong workforce is Thai.
- For six years there has been no lost time injuries (15.3 million hours worked)
- 31% management positions held by women
- A significant investment in education and training through scholarships, supporting minerals education at Thai universities and other initiatives
- Received the Thai National award for Health, Safety and Environment and the Prime Minister's Labour Relations award for the 5th consecutive year.

Thailand is a challenging country for mining companies to gain access to mineral resources. NGOs and community action groups are active. Mindful of this general anti-mining atmosphere, Akara has worked particularly hard on its community relations. In 2007, Kingsgate became the world's only miner to achieve the Social Accountability SA 8000 accreditation which is maintained to date. 60% of mining royalties go directly to local provinces and village councils. This totalled \$4.5 million in 2009.

The company has worked to meet various standards and codes including ISO 9001; ISO 14001; OHSAS 18001; ISO 17025; SA 8000 and the Cyanide Management Code.



Figure 4.7 - progressive waste dump rehabilitation at Chatree



## Monitoring During Operations

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.

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.

The MMG audit outcomes help to fulfil its 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 (see LP **Monitoring** p.96).

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. An excellent example of monitoring by a regulator is in the Northern Territory of Australia. The 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*.

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 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 (see LP **Monitoring** p.23).



Figure 4.8 - The Northern Territory's "Lab Truck"

## Hazardous Substances

### Introduction

Hazardous substances used and hazardous waste generated on mine and mineral processing sites may include:

- Acids (sulfuric, hydrochloric); contact with strong acid liquids or fumes is a human health hazard and may also cause structural damage in a facility. Releases of acid to the environment may have direct effects on biota but also solubilise and thus mobilise heavy metal toxicants, as described in the handbook *Managing Acid and Metalliferous Drainage*.
- Sodium cyanide for gold recovery in large operations. The handbook *Cyanide Management* provides extensive information about sodium and calcium cyanides, with particular attention given to mammalian toxicity and consequent environmental impacts. With regard to the environment, best practice is exemplified by adherence to the International Cyanide Management Code to which major gold mining organisations subscribe. The Code covers production transport, use and disposal of cyanides. The risk of cyanide poisoning is by ingestion and exposure to workplace vapours, mists and solution contact. It should be noted that, although small quantities of hydrogen cyanide are generated when sodium cyanide is exposed to moist air, only one person in two (for genetic reasons) is able to detect the odour of hydrogen cyanide.

- Mercury for gold recovery in small/artisanal operations. In other operations, workplace concentrations of mercury should be monitored routinely where exposure is possible, for example due to thermal desorption of metallic mercury. This can occur when ores (some zinc concentrates, for example) containing trace amounts of mercury are roasted. A case study of reduction of mercury pollution that could arise from artisanal mining is presented in the handbook *Risk Assessment and Management*. Assistance from the mining company operating nearby is provided under the United Nations Industrial Development Organisation Global Mercury Project.
- Metals as ions or complexes from Copper, Lead, Zinc, Nickel, Iron, Arsenic, Mercury and Cadmium sludges or solutions. Recovery of the metal is usually the object of the mining project but hazards may arise from the presence of toxic by-products (arsenic and cadmium for example) or metals released as a result of developing acidification, as described in the handbook *Managing Acid and Metalliferous Drainage*.
- Thiosulfates, polythionates, also resulting from acid mine water or processing solutions. Sodium dithionite generates sulfur dioxide in solution and may be stored on minesites as an alternative to gaseous sulfur dioxide. Accidental wetting of dithionite leads to an exothermic process that may produce sulfur dioxide fumes.
- Process reagents (acids, alkalis, frothers and collectors, modifiers, flocculants and coagulants which contain aluminium and iron salts and organic polymers. Recourse needs to be made to Material Safety Data Sheets for these substances for information that can lead to best practice management.
- Nitrogen compounds from blasting materials. In enclosed spaces the combustion products from nitrate explosives, predominantly ANFO at present, need to be dispersed before work can restart in the affected area. Best practice consists in adequate ventilation and monitoring of the workplace atmosphere, rather than the use of personal protective equipment.
- Oil and fuel used for engines, power plants, and lubrication. Although hydrocarbon products may cause dermatitis when skin is contacted, the main hazard is one of fire. Because considerable quantities of hydrocarbons may be stored on a minesite, their presence also constitutes a security hazard because they could be targeted in an attack. There are also the potential impacts on the environment from spills, storage tank leakage and accidental discharge.
- Suspended soils, mine water, surface drainage and process effluents. State and Territory regulations cover discharges to watersheds and water bodies, but best practice should go beyond mere compliance and seek opportunities to avoid environmental damage and to improve water quality.

- PCBs from transformers. Australia's *PCB Management Plan (1996)* has been taken up in State and Territory regulations. As a result of earlier efforts to remove PCBs from service, many transformer oils are actually dilute solutions of PCB in paraffin. Where the PCB content is 50 mg/kg (50 ppm) or greater, the material must be treated to destroy PCBs and reduce the level to 2 ppm or less. Although complete phase-out may still be some years away, most PCB-containing oil has been removed from service, and treated as required.
- Asbestos from various on-site plants including AC (Asbestos cement) sheets on old buildings. Asbestos lagging is seldom employed on pipework these days but some old plants may still contain this material. State and Territory regulations place restrictions on its removal and disposal.
- Surplus paints, pesticides and laboratory chemicals. Stored oil-based paints are fire hazards, while pesticides and laboratory chemicals may have human health and/or environmental impacts, or both. Chemical containers may contain residual chemicals that pose risks to human health and the environment. They should be disposed of safely. Clean containers may not be hazardous, and collection and recycling options may be available under the DrumMuster program for plastic and metal containers in which pesticides had been supplied.
- Solvents used in extraction plants. Hydrocarbon solvents such as kerosene are used in solvent extraction plants for separating complexed metal ions. As with the petroleum products described above, there are flammability hazards and also security risks.

## Managing Acid Mine Drainage

Although acid mine drainage is usually associated with hard rock metalliferous mines it can also manifest itself in coal mines and, in mineral sand mines. The **Cloverdale** mine is one of several mineral sand mines operated by Iluka Resources Limited (Iluka) in the south-west of Western Australia. The mines occur in deep sandy soils formed by marine regression and transgression events 1.5-2.3mya. AMD is a potential risk at these sites and is typically associated with fine-grained framboidal pyritic material in the pit walls, ore and overburden material.

In the early stages of mine planning at Cloverdale, a detailed survey was undertaken to map the extent of acid generating materials within the orebody and adjacent areas. The survey data and 3D model of acid generating materials assisted mine management to better understand the possible extent of AMD issues at the Cloverdale site. Mine planners have utilised this information during development of the mining schedule, to minimise the impact of AMD associated with pit dewatering, mining and handling of acid generating materials. The information has also been used to estimate AMD management (e.g. treatment) costs during operations, and the overall economic impact of AMD on the project. An AMD Management Plan was also developed for the site, to provide a basis for day to day management of acid generating materials throughout the mine life (see LP **AMD** p.41).



Figure 4.9 - Geological control to separate acid generating material

A risk assessment approach such as described in Section 7.1 of the Risk Handbook and the **Tom Price** case study (see LP **AMD** p.44) can provide input to the design of new projects, to ensure that the next generation of mines has the best possible chance of effectively managing AMD and enhancing sustainable development. Acidic and metalliferous drainage as well as spontaneous combustion (self heating) problems are known to be associated with the iron ore deposits that mine un-oxidised Mount McRae Shale (MCS) as waste in the Hamersley Province of Western Australia. When un-oxidised, the MCS is a black, carbonaceous and sulfide bearing shale (pyritic black shale) that poses both an AMD and self heating risk.

Management of pyritic black shale at Tom Price, and all other Rio Tinto Iron Ore sites in the Hamersley Province, is carried out in accordance with a Black Shale Management Plan. The management strategy utilised in the plan is broadly based upon the following principles: (1) identification of black shale distribution and character; (2) minimisation of exposure and mining of pyritic black shale; (3) identification and special handling of pyritic black shale that must be mined; (4) encapsulation of pyritic black shale inside inert waste rock dumps to limit water contact and allow the dumps to be revegetated; and/or (5) placement of pyritic black shale below the water table in backfilled open pits. Assessment of the plan has indicated that it has been successful in preventing spontaneous combustion. In regard to AMD, however, it has been concluded that pyritic oxidation can still occur throughout the dumps and generate pollutants that have the potential to lead to AMD. Consequently, Rio Tinto Iron Ore has initiated a detailed AMD mitigation and management strategy that aims to preserve the environmental values of the regional water resources.



Figure 4.10 - Black shale at Tom Price

## Risk in operations

### Introduction

The environmental and economic risks of mining are generally well identified and managed, but social risks remain a more challenging area for the minerals industry. Social risk can manifest in a variety of ways—through Indigenous issues, community development, workforce issues and so on. The relationships between social, environmental and economic risks are often not clearly defined or easy to clarify—yet they must be incorporated into risk management to ensure the minerals industry contributes strongly to sustainable development.

The **Argyle** mine provides an example of the use of risk management in a technically, geographically, environmentally and socially complex operation (see LP **Risk** p.10). In December 2005, Rio Tinto approved a major investment to extend the Argyle Diamonds mine into an underground block cave operation. As would be expected for an investment of this size, the feasibility study included a comprehensive risk assessment covering all aspects of the proposal. These included not only the financial and technical risks associated with the change to a new mining method, but also the environmental and social implications. The team charged with assessing these sustainable development implications focused, in particular, on the impacts of the decision on two communities, the first the mainly Indigenous regional population of the East Kimberley area where the mine is located and the second the large number of people involved in processing Argyle's diamonds downstream in India—an estimated 220 000 workers. Team-based workshops were used to address the social risks and opportunities for the two community areas. The outcomes were readily integrated into the overall risk register for the project. New controls were developed for key areas and the residual risks recalculated. The social risks were among the

highest rating group for the whole project. As the industry integrates sustainable development considerations into its decision making processes, the treatment of external socio-economic risks and opportunities will become increasingly important. The 'mainstreaming' of these issues into risk management processes reflects their significance and importance to most large mining and processing operations.



Figure 4.11 Argyle Diamond mine

### **Environmental Risk Management**

Environmental risk may be defined in two ways. Firstly, and more commonly, environmental risk can be defined in terms of the impact of exploration, mining or mineral processing activities on the environment. Secondly, environmental risk can be thought of in terms of environmental factors or 'Acts of God' which may present a risk to the sustainability of the operation. For example, a major rainfall event flooding a mine or causing overtopping of process water, or the converse—a long dry period during which water supply cannot meet demand.

Environmental risks from an operation's activities and their potential impact on the environment and local community may have a range of impacts on the business, such as community health impacts, public outrage leading to reputation damage, cost of closure and rehabilitation, and ongoing legacy risks after closure.

Opportunities may also arise from risks to the natural environment. For example, in an area where artisanal and small-scale mining is being practised by a community, the business may share its knowledge and tools with those artisanal miners to reduce their impact on the community and natural environment. **AngloGold Ashanti** is addressing this issue at a number of its operations in Africa (see LP **Risk** p.20). The company is exploring the possibility of allowing artisanal miners to work areas of its land where there is insufficient gold to justify commercial mining, but which could be successfully exploited on a smaller scale. This would help to legitimise artisanal mining, promote communications with local communities and reduce disturbance to the company's operations.



AngloGold Ashanti also plans to help reduce mercury pollution from artisanal mining by offering miners cleaner technologies in partnership with the United Nations Industrial Development Organisation Global Mercury Project.



Figure 4.12 - Artisanal Mining in Tanzania

## Stewardship

The mining industry's social licence to operate, to market and to develop is under increasing pressure, as the community becomes more educated, informed and aware. Additional pressure is coming from the downstream users of the mining industry's products. These processors, manufacturers, users and recyclers are being pressured by their stakeholders to identify the primary sources of commodities.

The global uranium market is forecast to undergo a major expansion due to an anticipated increase in global demand for uranium, rising uranium prices and growing recognition of the potential greenhouse benefits of nuclear power. Long-term management of nuclear waste is a stewardship issue that requires industry, government and the community to reach agreement on appropriate treatment techniques and sites for repositories. Such agreement has so far been reached in some but not all relevant countries (see LP **Stewardship** p.6).



Figure 4.13 - Beverley uranium mine site in South Australia

Xstrata's **Mount Isa** mining and smelting operations are world-renowned. Unlike many mining operations in Australia, Mount Isa is in very close proximity to its community and thus its operations are under constant scrutiny. By undertaking leading practice in materials stewardship the company is both able to demonstrate its sustainability credentials and reduce costs (see LP **Stewardship** p.22). Xstrata Copper is demonstrating its commitment to materials stewardship and integration of its operations by:

- increasing recovery of sulfur dioxide (SO<sub>2</sub>) from the copper smelter at Mount Isa Mines and its conversion into acid for use in fertiliser manufacture.
- optimising performance of the acid plant thus reducing the need for supplementary sulfur feed.
- reducing fugitive SO<sub>2</sub> emissions and making them available for conversion to acid .
- utilising a waste from the Townsville Copper Refinery to process electrostatic precipitator (ESP) dust, thereby maximising copper recovery while, at the same time, creating a beneficial use for a waste and integrating downstream processing facilities with the smelter.

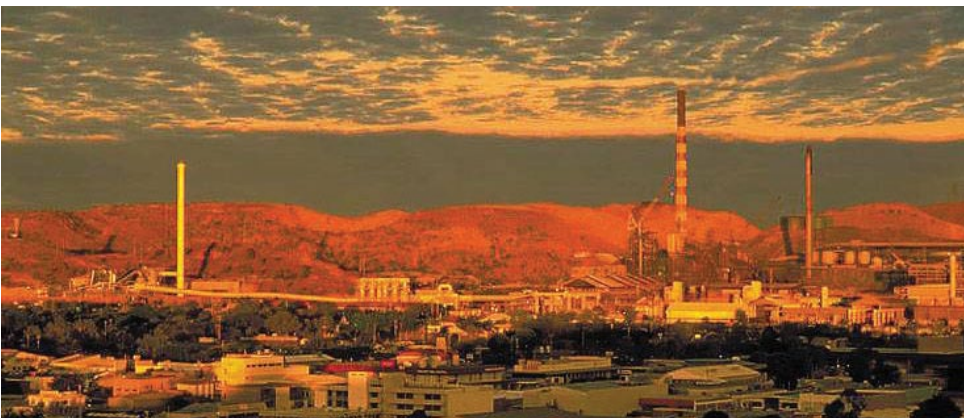


Figure 4.14 - Mount Isa illustrating the copper smelter and acid plant

An international example of stewardship or using innovative techniques for resource extraction is the Quang Ninh coal mining region in northern Vietnam. By utilising efficient longwall extraction, surplus funds are used for rehabilitation of old waste spoil piles.

**MINE:** Underground and open pit coal mines

**LOCATION:** Quang Ninh province, Vietnam

**BRIEF DESCRIPTION:** Application of new technology into underground coal mining in Vietnam.

**AREA OF LEADING PRACTICE:** Resource utilisation; new technologies/risk management being implemented

**DESCRIPTION OF INNOVATION:**

Underground mining has been operating in Quangninh province, Vietnam since the early 20th century. However, due to both the complications of geological/geotechnical/mining conditions and outdated equipment, coal production in Quangninh remained at 4 to 6 million tonnes per year for many years. Almost of the longwall faces at that time were supported by wooden props, causing the low output and productivity, and low standard of safety management. Since the 1990s, the Vietnam National Coal - Mineral Industries Holding Corporation Ltd. (VINACOMIN) has been applying advanced science and new technology into almost every stage of mining production, including: coal extraction, roadway development, underground transport, gas management, ventilation, water degradation, and environment protection in order to improve coal production and safety management. Recent improvements include: the application of the hydraulic props, moving girder hydraulic shields or mechanized shields to replace wooden props in supporting the longwall face; new types of transport in mines such as conveyors, hanging conveyor, extendable conveyer also have been applied to replace the inefficient kinds of transport in underground mine such as wagon pulling by locomotives; some types of transportation for workers in underground such as winch assisting workers walking in underground mines, infinite winch used for transport workers from surface to the working places to reduce the time and minimise the impact on employees' health. At present, the gas content in the coal seams in the Quangninh coalfield has been determined and the database of coal seams according to gas content has been established and classified. This database can assist the mine planners to design the strategies for preventing the potential problem of spontaneous combustion in underground mines. In addition, almost all of underground coal mines have been equipped with methane tracking stations to monitor the gas content in underground so that the potential problems can be prevented. This improvement has resulted in a dramatic increase in coal production, productivity, coal recovery, and the standard of safety management. For example, the output from a longwall face increased from 40,000 - 60,000 tonnes per year (the face supported by timber props) to approximately 250,000-500,000 tonnes per year, the productivity increased

from 2.5 - 3.0 tonnes/man-shift to 15.0 - 20.0 tonnes/man-shift. The total coal product produced by VINACOMIN increased rapidly, from 9 million tonnes in 1995 to 44.4 million tonnes in 2009 (an increase rate of 15-20% per year). In addition, because coal from the face was extracted and loaded to the conveyor by the machine instead of manually, and the faces were supported by mechanized shields with high loading capacity, the working condition of the miners and the standard of safety management are much improved. Experiences from underground coal mining in Vietnam has proved that sustainable development can be achieved by implementing advanced technology with the trend of mechanization, automation, computerization into mining operations.

The benefits to the community include:

- Extraction of a valuable resource that would otherwise remain in the ground
- Numerous jobs for the local community
- By continuing to operate the underground mine, funds are available for rehabilitation of the adjacent surface mine dumps (figure 4.16)



Figure 4.15 - Longwall face supported by mechanized shields, extracted by the shearer applied at Vangdanh coal mines in 2007

\* contributed by: Hong Quang - Vinacomin



Figure 4.16 - View over Ha Long Bay from top of waste dump

## Tailings Management During Mining Operations

### The Business Case for Leading Practice in Tailings Management

The business case for applying leading practice in tailings management is compelling. The failure or poor performance of a tailings storage facility can have a profound impact on the corporate bottom line. In extreme cases, tailings storage facility failures have severely eroded share value as the market anticipates the cost of cleanup, suspension of operations and possibly mine closure. This is in addition to the loss of company reputation and the loss of a social licence to operate. The cost of leading practice tailings management systems is more than offset by the reduced risk of a major incident.

Conventional economic analysis can lead to minimising initial capital expenditure and deferring rehabilitation costs. Net present value analysis discounts the current cost of future expenditures on closure, rehabilitation and post-closure management. Therefore, if this short-term economic perspective is taken, without taking into account the longer-term social and environmental costs, there is little motivation to invest more substantially at the development stage to avoid or reduce expenditures at the closure stage. There is a number of reasons, however, for applying leading practice at the earliest stage of development, and in designing and operating the tailings storage facility (TSF) to optimise closure outcomes. Designing and operating for closure of a TSF can avoid significant earthworks expenditures to re-establish stable landforms and drainage systems. Progressive rehabilitation, where possible during operations, enables rehabilitation work to proceed while there is an operational cash flow, and management and resources available. Progressive rehabilitation can also reduce the cost of financial assurance required by regulatory agencies. Leading practice tailings management will also minimise the time required for post-closure monitoring and maintenance.

### Tailings and risk

Tailings are an inevitable consequence of most metalliferous mining operations as well as certain coal mines and industrial mineral operations. The management of a TSF present mine managers with some of their most challenging sustainability issues. Indeed many premature mine closures are caused by failure of the TSF.

Many companies have implemented innovative leading practices to reduce the risk of a failure of a TSF or the risk of negative environmental and community impacts from dust etc. In recent times for example there has been an increasing use of the Robinsky or Central Thickened Discharge method of tailings disposal. Sunrise Dam gold mine (SDGM) located 55 km south of Laverton in WA, commenced operation in 1997. A "paddock style" TSF for conventional medium-density tailings slurry was commissioned for the design throughput of 1.5 Mtpa. One downstream raise was carried out in 1998 prior to decommissioning in 1999. Design throughput was scheduled to increase from 2 Mtpa in 2000 to 3 Mtpa in 2003, and it was decided to thicken the tailings to a higher density and change to the central thickened discharge (CTD) method of tailings disposal in a new location. The design area of the CTD TSF in 1999 was 300 ha and eventually increased to 330 ha (see LP **Tailings** p.55).



Figure 4.17 - Sunrise Dam TSF

### **Tailings Minimisation, Recycling and Reuse**

In common with the generic waste management hierarchy, mines need firstly reduce tailings production, and then to recycle and reuse the tailings where possible. The aim should be for cleaner and more targeted mineral processing that minimises the production of tailings. Every opportunity for their recycling and reuse should also be explored. In many instances, tailings have inherent value, through reprocessing or via other industrial uses. For this reason, the disposal of tailings in a way that will make tailings recovery or re-treatment uneconomic, or prevent future mining activities is often actively discouraged. Extreme examples would be underground and pit backfilling.

Historical gold tailings are the prime example of changing technology providing a means to make re-processing viable, and this holds true today for a range of other types of mine tailings.

There is an opportunity to use some tailings for industrial or environmental purposes, thus reducing the storage requirement. Examples of these are:

- the finer portions of fly ash used as a pozzolanic in the manufacture of cements;
- power station bottom ash used as inert building fill;
- red mud from the alumina industry used as a soil conditioner and to clean polluted water streams;
- power station ash used to fill coal mining voids; and
- coal tailings used as a low grade fuel.

Australian alumina operations are applying leading practice in tailings disposal and a good example is Alcoa's operations in Western Australia.

**MINE:** Alcoa bauxite mines

**LOCATION:** Western Australia

**BRIEF DESCRIPTION:** Surface bauxite mining

**AREA OF LEADING PRACTICE:** Tailings disposal; Rehabilitation; closure and completion

**HANDBOOK(S) REFERENCE:** Tailings; Mine rehabilitation; mine closure and completion

**DESCRIPTION OF INNOVATION:**

Alcoa World Alumina Australia currently produces 7.3 million tonnes of alumina annually at its Western Australian refineries located at Kwinana, Pinjarra, and Wagerup. These refineries utilise bauxite mined in the nearby Darling Range. This ore is low grade by world standards as two tonnes of residues are produced for every tonne of alumina extracted.

Storage of this residue poses some major environmental challenges. The refineries are located close to major population centres and adjacent to some of the state's most productive land, the volume of waste produced is very large, and the alkalinity of the waste has the potential to impact valuable surface and ground water resources.

There were a number of environmental and process reasons why the storage of low density "wet" tailings in large impoundments was not the preferred technique for future tailings storage. Development work began in the early 1980s on alternative techniques and in 1985 "dry stacking" was adopted for Alcoa's Western Australian refineries. Dry stacking utilises a large diameter Superthickener to de-water the fine tailings, which is then spread in layers over the storage areas to de-water by a combination of drainage and evaporative drying. By utilising the coarse fraction of the tailings for construction of drainage layers and upstream perimeter embankments, the storage area can be constructed as a progressive stack, thus avoiding the need for full height perimeter dykes and allowing continued stockpiling on areas which were previously "wet" impoundments.

Routine ploughing of the mud with mechanical equipment has been termed "mud farming". Mud farming helps achieve a maximum density which allows the dry stack to be developed with maximum outer slopes (a minimum strength of 25kPa is achieved allowing an outer slope of 6:1 to be maintained), and maximises the storage efficiency of the stack.

Mud farming also minimises the potential for dust generation, which is important given the location of the refineries close to residential areas. Ploughing the surface presents a wet surface, buries carbonate, and provides a surface roughness that prevents dust lift-off once the tailings have dried.

Dry stacking bauxite residue is now fully operational at all three of Alcoa's Western Australian refineries. A number of operational techniques have been developed to optimise the slurry distribution and drying processes, and these have now become standard practices. The advantages of reduced environmental risks and lower overall storage costs are now being realised.



Figure 4.18 - Using a D6 Swamp Dozer to enhance the drying rate.

## Water Management

### **The Business Case for Water Management**

There are clear economic, environmental and social reasons to achieve it. Impacts of sub-standard water management may not only be felt at a local level but may escalate rapidly to become national and international issues, consuming large amounts of resources. Too often water management is reactive and, because water is intimately linked to climate variability, there is a risk that management priorities become closely tied to current conditions; that is, excessive attention in times of scarcity or excess and none otherwise. There are financial consequences of poor operational water management. Running out of water can cost money in lost production and high water prices. If water is poorly managed, product quality can be compromised. Both these risks can result in loss of market share. Poor management of excess water can result in fines, loss of reputation and difficulties with environmental approvals. These risks can also cause issues with local communities and other water users, which may be very expensive to remedy in the long term. Lack of attention to the environmental and social services from water can erode the social licence to operate.



Beyond the operation, poor reputation for water management can contribute to loss of investment attractiveness, destruction of shareholder value, access to other resources (water, ore, land), licence to operate and difficulties in the area of attraction and retention of key staff. These strategic risks may be far more financially damaging than those at the operational level. The **Bulga** mine is an example of a company managing these risks.

Xstrata Coal New South Wales's open cut Bulga mine has traditionally been reliant upon the local Hunter River to extract water by licence for use in the washing and mining processes.

Following severe dry weather experienced in 2007, the mine identified water security as a risk which needed to be addressed. In response, the mine investigated new opportunities to decrease its reliance upon the Hunter, increase water security and more effectively use stored water on site. As a result, a series of new initiatives were put in place to improve onsite water management and implement more effective conservation procedures. Actions taken included:

- Long and short term water balance models - Xstrata Coal NSW engaged water management consultants to develop short and long term water balance models to assist in making day to day decisions about water transfers, discharges and licence allocations (short-term) and to simulate mine supply, demand and storage requirements over the life of the mine under various climatic scenarios (long-term).
- The long term water balance model identified the benefits and desirable size of additional on-site water storage, which would substantially reduce the requirement for Hunter River water and the need to discharge mine water off site. In response, a 3,000ML dam is currently being constructed to better capture mine spoil runoff to be used in the washing process and for dust suppression.
- Tailings Flocculation - A secondary flocculation system was installed within Bulga's tailings system, allowing water to be released from the coal tailings faster and thereby increasing the amount of water available for recycling. This action also consolidated Bulga's tailings faster, providing a more stable surface for rehabilitation.
- Underground Raw Water Reuse - Historically, approximately 35 megalitres of Hunter River water was used per month for dust suppression at the Bulga open cut and wash down and cooling in the Bulga underground (Beltana) longwall and development mining.

Once the water is used underground the majority of it drains back through the goaf, mixes with mildly saline coal seam water and reports to the dewatering bore which discharges approximately 50ML/month into the complex raw water system. Analysis of the dewatering bore discharge showed it to be slightly hard, higher in salinity and occasionally substantially higher in suspended solids than Hunter River water. It was then determined that with an appropriate filtration system, monitoring and routine de-scaling of the longwall and development machinery dewatering bore discharge could be reused instead of Hunter River water. As a result, a 200 micron automatic cleaning AMID filtration system was installed.

Since March 2008 all of the raw water used at the Beltana underground mine has been supplied from the goaf dewatering bore, reducing the draw on the Hunter River, without affecting mining activities.



Figure 4.19 - Water sampling at Bulga

### **Water management systems**

As expressed in the first chapter, it should not be presumed that a given operation needs to achieve leading practice in all aspects of its water management system since to do this may demand allocation and mobilisation of resources (such as people and money) in excess of the benefit to be gained. Potentially this could detract effort from management of other risk areas. Operations should select the leading practices that mitigate the risks based on their individual business case which must be managed to suit its economic drivers, legal and sustainable development requirements and that of its owners/shareholders.

Leading practice operations make this selection by means of a risk-based assessment of key aspects of water management (as demonstrated in the Rio Tinto diagnostic case study). Typical tasks and responsibilities relating to water management on a mine site are illustrated in Table 4.1.

**Table 4.1 - Typical tasks and responsibilities for each of the teams managing water on mining operations**

<b>Area</b>	<b>TASK</b>
Corporate	<ul style="list-style-type: none"> <li>Development of strategic water management plan</li> <li>Engagement with government–approvals</li> <li>Formulation of sustainable development strategy—including compliance and external reporting</li> <li>Formulation and communication of company-wide strategies, processes and plans</li> </ul>
Mining/operations	<ul style="list-style-type: none"> <li>Managing storages, roads and drainage to meet licence regulatory requirements (not necessarily–may be environment)</li> <li>Development of site water management plans and balances</li> <li>Water risk assessment and management</li> <li>Supply/demand management</li> <li>Pit and advance mining dewatering</li> <li>Flood and drought management contingency plans</li> <li>Dust suppression (typically roads, stockpiles and conveyors)</li> <li>Vehicle wash down (minor)</li> <li>Building and maintenance works</li> <li>Closure implementation–water and tailings</li> <li>Fire and potable water</li> </ul>
Mineral handling and processing	<ul style="list-style-type: none"> <li>Separation of mineral and gangue materials</li> <li>Tailings and reject management</li> <li>Process water and recycling management</li> <li>Dust suppression–stockpiles, conveyor and drainage of industrial area</li> </ul>
Environment and community	<ul style="list-style-type: none"> <li>Rehabilitation planning</li> <li>Closure planning</li> <li>Water flow and quality monitoring</li> <li>Onsite and surrounding ecosystems management</li> <li>Participating in regional and local water planning</li> <li>Engagement with TOs, NGOs, key stakeholders</li> <li>Corporate reporting–internal and external</li> </ul>

The design and performance of the water management system at any given operation will be a function of the corporate, legislative, climatic and local community environments in which they operate. Water management will only improve with the personal leadership and specific mandate of executive management and the proactive commitment of those directly responsible for managing water at the operation; that is, the site manager and team.

The Rio Tinto “Excellence in Water Management” diagnostic methodology was developed to provide a holistic assessment of water management at an operation (mine site, smelter etc). The full engagement program takes the operation from initial risk-based performance assessment relative to key performance areas (KPA), to risk reduction opportunity workshops and finally to project planning and scheduling of prioritised action plans. As at end 2007, Rio Tinto has utilised this diagnostic methodology at more than 25 of its operations globally, giving rise to projects that reduce water-related risk and improve water efficiency at the operations. Leading practice and high-risk trends are identified from these operational reviews allowing targeted corporate programs to be developed (see LP **Water** p.16).



Figure 4.20 - Participants at a workshop

The importance of on-going community consultation is highlighted in the *Water and the Community* case study from the Water Management Leading Practice Handbook. Iluka has been extracting mineral sands in the drought-prone Wimmera region of Victoria for many years. Iluka recognised in the initial planning stages for the development of operations in the Murray Basin that water would be an issue requiring extensive stakeholder engagement and agreement. Without early consultation, the current operations could have been severely disrupted by a lack of water due to drought conditions (see LP **Water** p.40).



Figure 4.21 - Iluka staff engaging with the local Wimmera community

### Integration of water supplies

Leading practice dictates that supply of water to even a single component/process within the operation must be considered in a holistic way. The site operational simulation model with linked water quality requirements and constraints is the best tool for analysing options. The need for additional draw on new water resources outside of the existing water circuit needs to be fully justified. This includes a cost analysis and consideration of life-of-mine requirements. Integration provides significant synergy and opportunities, while short-term single-user solutions may become long-term liabilities. In some cases, it is possible to reduce overall water consumption by integrating sources from nearby mines. Redirection of groundwater from mine operational dewatering at one mine rather than continuing to extract from a separate borefield at another is an active development in a number of Pilbara iron ore mines, for example, **Paraburdoo** and **Mt Whaleback**.

BHP Billiton Iron Ore manages two satellite ore bodies, Orebody 23 and Orebody 25 situated approximately 12 kilometres and eight kilometres to the east of Newman and the company's Mt Whaleback operation. Mining of both ore bodies requires lowering of the water tables through the use of dewatering bores.

The Mt Whaleback mine west of Newman has a large process water demand. Rather than develop local groundwater sources which would potentially be lower cost, the dewatering water from Orebody 23 and Orebody 25 Pit 3 is pumped about 13 kilometres and against a static head of 90 metres to a storage tank which then provides a gravity supply of process water. By utilising the dewatering water across this interconnected system between Orebody 23, Orebody 25 and Mt Whaleback, the overall groundwater abstraction is minimised, reducing the impact from mining operations (see LP **Water** p.51).

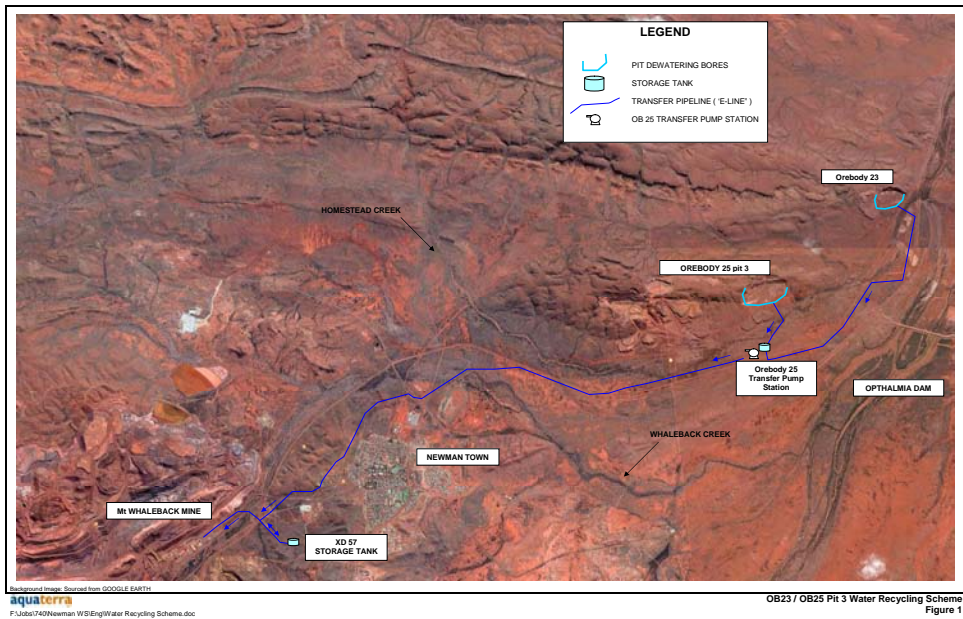


Figure 4.22 - Mt Whaleback water supply system

Integration of the operational water supply system within the regional supply system provides benefits. In **Weipa**, selective use of different water sources has improved water security, reduced costs through increased reuse and benefited the reputation of the operation (see LP **Water** p.52). Bauxite mining operations at Rio Tinto Aluminium Weipa occur in a region of water excess, due to the tropical and monsoonal climate. The mine has multiple sources of water to draw from, each of which has its associated costs and additional values. The four main sources are decant water from the tailings dam; site rainfall runoff captured in 'slots' and other small storages across the mining lease; shallow aquifers underlying the area; and the deeper aquifers of the Great Artesian Basin. Availability of the different sources can vary during the year, particularly the first two sources.

In other situations, such integration offers increased efficiency and opportunities in terms of water trading, particularly with respect to waters of differing quality. For example, the cost of plant modifications to use poor quality water may be off-set by gains in trading good quality water entitlements to other users. Similarly, water sharing arrangements between adjacent mines may reduce the burden on one to dispose of excess water, allow the second to access the worked water and thereby potentially free up fresh water for other uses in the catchment. This type of approach is increasing in application in the Hunter Valley in NSW, for example.

### **Site water use**

Water is used for numerous tasks across the mine site and will depend on the type of operation. Leading practice mines minimise water use while maximising water reuse. Water reuse is defined in a number of ways and is also often used interchangeably with water recycling. Water reuse minimises demand for water from off site and thereby focuses attention on leading management practices within the site. Leading operations generally have better control over water releases because reuse is carried out extensively and consistently.

Olympic Dam recognises that the responsible use of Great Artesian Basin (GAB) water is essential to protect the environmental values of the GAB springs, a key concern for some of its stakeholders. The mine monitors the rate at which it extracts water from the two wellfields to ensure that it is always within prescribed limits and that adverse impacts are not occurring. The ongoing challenge is to continue to meet these limits while providing the opportunity to optimise plant production rates. The project confirmed the importance of regular inspection, testing and calibration of process indicators. Significant water savings have been identified and implemented in the three key production areas (see LP **Water** p.57).



Figure 4.23 - Main shaft at Olympic Dam

### **Re-injection into watercourses**

Re-injection is the practice of replacing groundwater into the same or a nearby aquifer. It can be achieved using engineering infrastructure and/or passive re-infiltration via local water courses. In some circumstances it is preferable to releasing water into surface water systems and/or relying on evaporation. Re-injection is considered water diversion when the receiving aquifer is within the lease boundary and as an output when it is outside the lease boundary.

Company policies and government regulations are increasingly requiring such actions to provide better stewardship of water resources. Re-injection requires specific geological and hydrogeological conditions with the added aim of being economically feasible. A re-injection operation should be located in:

- geology that has the capacity to receive water at a sufficiently high rate; that is, exhibit at least moderate permeability).
- an area with a sufficiently deep naturally occurring water table.
- areas where the injection quality of injected and receiving waters are compatible.
- located within a reasonable distance of the abstraction source to minimise infrastructure costs, but not so close that dewatering operations are inhibited due to recirculation.

Not all these conditions may be met in all situations where it might be desirable to use re-injection. One example where re-injection is proving feasible is the **Yandicoogina** iron ore mine in the Pilbara in Western Australia. Mining commenced at Yandi in 1998. A fines iron ore product is produced from the Channel Iron Deposit (CID) ore body. Dewatering is required as the CID ore body is within a significant aquifer system. It is currently standard regional practice to discharge surplus water into existing waterways. However, this has several associated risks including the potential to develop dependent riparian ecosystems on the year-round water supply, in the process losing their adaptation to ephemeral wet season flows. In addition, this discharge may be considered wasteful by other stakeholders, particularly in the dry Pilbara region. Aquifer re-injection allows a component of the water extracted to be returned to the environment, limits impact on downstream surface ecosystems, minimises potential discharge impacts on the surrounding environment, and preserves a valuable resource that may be stored and withdrawn in the future. It is important to recognise that although re-injection has been successfully implemented at Yandi, the application of this technology is dependent upon several factors, in particular, the site-specific hydrogeological conditions. Re-injection should not be considered the 'silver bullet' for dealing with all excess water management situations. For those operations where it is appropriate, aquifer re-injection can be a powerful tool for the mining community to utilise in order to preserve the groundwater resource and riparian ecosystem integrity (see LP **Water** p.79).





Figure 4.24 - Mine dewatering water re-injection at Yandicoogina

## 5.0 MINE REHABILITATION AND CLOSURE



Figure 5.1 - Agricola Mine in Queensland before and after rehabilitation (courtesy of SMI)

### Key Messages

- All mines close and many close prematurely. Mine management needs to develop and implement mine closure planning. Taking a more integrated approach to mine closure planning, and doing it earlier, can achieve effective mine closure and completion, and ameliorate the negative effects of unexpected or unplanned closures.
- Community engagement at the earliest possible time is essential. The goal should be community ownership as the community will inherit the project eventually. Community liaison or advisory groups established specifically for the mining project can help the operation focus its engagement program.
- Rehabilitation planning and implementation need to take place early and progressively throughout the life of the mine. Leading practice techniques can provide guidance for successful landform design, topsoil usage and revegetation outcomes.
- Costing for closure and rehabilitation is essential and tools are available to calculate realistic costs.
- Risks (to company reputation etc) are significant and are long term in nature and companies can expect to have rehabilitation and closure liabilities long after production has ceased. Quantitative and qualitative risk assessment techniques to demonstrate to the community and regulators that closure issues have been identified and an appropriate security deposit can be calculated.
- Leading practice biodiversity management goes beyond minimising long-term impacts from operations. It identifies opportunities for improvement in the lease and adjacent areas by introducing innovative and sustainable land management practices.
- Leading practice techniques during the operation of the mine will reduce the potential for long term issues associated with acid mine drainage.

## Introduction

In a perfect world, mines only close when their mineral resources are exhausted and a mine closure plan is in place and progressively implemented. There is time available for planning, monitoring and trials, and funds are externally held to cover the costs of implementing the closure plan. Pre-determined outcomes can be achieved or progressed satisfactorily and there should be ample opportunity to overcome any major issue that may create problems after closure. Stakeholders are prepared for the intended closure date, employees can plan to find alternative employment, and the community has the opportunity to work with the mine to ensure sustainable benefits from the mining activities.

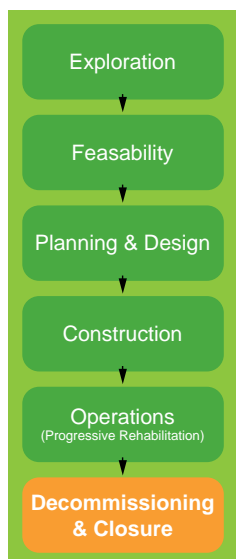
However, in the real world, mines extract reserves not resources, and the grade and tonnage of reserves vary from day-to-day depending on the commodity price, ore quality or grade, further exploration results, geotechnical complications and other factors which can result in mine closure before the estimated reserve has been fully extracted. This situation can create significant problems for the mining company, the community and the regulator.

There are many reasons why mines may close prematurely. Research shows that almost 70 per cent of the mines that have closed over the past 25 years in Australia have had unexpected and unplanned closures (Laurence, 2006). That is, they have closed for reasons other than exhaustion or depletion of reserves. These include:

- economic, such as low commodity prices or high costs that may lead a company into voluntary administration or receivership.
- geological, such as an unanticipated decrease in grade or size of the ore body.
- technical, such as adverse geotechnical conditions or mechanical/equipment failure.
- regulatory, due to safety or environmental breaches.
- policy changes, which occur from time-to-time, particularly when governments change.
- social or community pressures, particularly from non-government organisations.
- closure of downstream industry or markets.
- flooding or inrush.

Poorly closed and derelict (orphaned and abandoned) mines provide a difficult legacy issue for governments, communities and minerals companies and, ultimately, tarnish the mining industry as a whole. Increasingly, as access to resources becomes tied to industry and corporate reputation, effective closure processes and satisfactory mine completion becomes critical to a company's ability to develop new projects. Poor planning and inadequate financing commonly increase the costs of closure and decrease overall profitability, hampering a company's ability to develop new projects. Taking a more integrated approach to mine closure planning, and doing it earlier, can achieve effective mine closure and completion, and ameliorate the negative effects of unexpected or unplanned closures.

Closure involves the implementation of the closure plans developed in the earlier stages of the mining cycle, the conduct of the necessary investigations and studies to identify potential contamination, and confirmation that the agreed outcomes and criteria have been met.



Activities at this stage will include:

- demolition and removal of infrastructure.
- reshaping of remaining mining landforms.
- completing the rehabilitation and remediation processes.
- monitoring and measuring the performance of closure activities against the agreed standards and criteria.
- inspections, consultation and reporting to stakeholders on progress.
- progressive community and government sign off.

This chapter focuses on both the rehabilitation and closure phases of the mining life cycle. It bears repeating that both processes should be commenced early and continue throughout the mine's life.

## The Business Case for Sustainability in Mine Rehabilitation and Closure

The business case for approaching mine rehabilitation and mine closure within a sustainable development framework in a planned, structured and systemic manner that is progressively implemented over the whole project cycle includes:

- Improved mine management
  - opportunities to optimise mine planning and operations during active mine life for efficient resource extraction and post-mining land use (for example reduction of double handling for waste materials and topsoil and reduced areas of land disturbance)
  - identification of areas of high risk as priorities for ongoing research and remediation
  - progressive rehabilitation provides opportunities for testing and improving the techniques adopted
  - lower risk of regulatory non-compliance
  - progressive implementation of a mine closure plan with opportunities for ongoing effectiveness testing, assessment and feedback

- Improved stakeholder engagement in planning and decision-making
  - more informed development of strategies and programs to address impacts, ideally as part of a community development approach from early in the mine life
  - improved community receptiveness to future mining proposals
  - enhanced public image and reputation.
  - understanding the likely impacts on affected communities in terms of environmental, social and economic impacts of mine closure
  - informed development of strategies and programs to address closure impacts, ideally as part of a community development approach from early in the mine's life
  - increased support from employees, government, landholders, local community and other stakeholders for closure decisions.
- Reduction of risks and liabilities
  - assured financial and material provision for mine rehabilitation and closure through early and more accurate estimation of mine rehabilitation and closure costs
  - reduction of exposure to contingent liabilities related to public safety and environmental hazards and risks.
  - continual reduction of liabilities by optimising operational works during active mine life in alignment with closure plan
  - reduction of ongoing responsibilities for the site and facilitation of timely relinquishment of tenements and bond recovery.

## Biodiversity and Closure

### Introduction

An example of taking biodiversity into account when closing a mine is the **Timbarra** gold mine. The primary aim of revegetation was to re-establish the majority of target vegetation consistent with the seven natural vegetation communities that occurred in the area disturbed (LP **Closure** p.25).



Figure 5.2 - Habitat corridor Timbarra gold mine

An example where mining companies can have a positive effect on biodiversity is the jarrah forests of Western Australia (LP **Biodiversity**). A plant disease (dieback) caused by the introduced soil-borne pathogen *Phytophthora cinnamomi*, can lead to severe degradation in the most susceptible sites. Many of the dominant jarrah species (*Eucalyptus marginata*) are killed in these infested areas, along with a range of mid-storey and understorey plants. This can result in significant impacts on the biodiversity values of severely affected areas. Alcoa's bauxite mining operations occur in the jarrah forest and degraded sites are present within the mine envelope. In 1979 the company made a commitment to support a rehabilitation program for these sites within the mine envelopes of its three mines.



Figure 5.3 - Dieback rehabilitated area

**MINE:** Jarrahdale bauxite mine

**LOCATION:** Jarrahdale Western Australia

**BRIEF DESCRIPTION:** Surface bauxite mining

**AREA OF LEADING PRACTICE:** Rehabilitation; closure and completion

**HANDBOOK(S) REFERENCE:** Mine rehabilitation; mine closure and completion

**DESCRIPTION OF INNOVATION:**

The published rehabilitation objective at Alcoa's WA bauxite mines is '... to establish a stable, self regenerating Jarrah forest ecosystem, planned to enhance or maintain water, timber, recreation, conservation and/or other nominated forest values'. Achieving such a broad objective to the level expected by society, however, required the evolution of increasingly stringent, specific targets and operating standards. This in turn depended on the constant evolution of improved restoration technologies, requiring significant levels of ecological research.

Alcoa's completion criteria contained broad guidelines about how an area of rehabilitation would be relinquished and a certificate of acceptance issued, but no detail about how this would be administrated. An area containing 975 ha of rehabilitation at the Jarrahdale Mine was identified as the first area to be submitted for a certificate of acceptance; and subsequently the first certificate of acceptance for a significant area of mining rehabilitation in Australia was issued in November 2005. This represented about a quarter of the area mined and rehabilitated at Jarrahdale. A second area that includes 380 hectares of rehabilitated land has subsequently been signed off and two further areas have been submitted.

Substantial areas of Jarrahdale have met the required completion criteria. This should allow these areas to be managed in an integrated manner with the surrounding unmined Jarrah forest. Although the rehabilitated areas are not identical to the pre-mined condition, all the sites at Jarrahdale have reached approximate compositional goals to unmined sites and to have demonstrated processes of self-perpetuation. Key components of Alcoa's strategy have been a commitment to study the baseline native ecosystem and the restored ecosystem, and to seek convergence in similarity of biodiversity and function. Specific applied knowledge gained from this research are the use of direct-returned topsoil; the sowing of seed of a wide range of native species; the proximity of colonization sources for other species; propagation and planting of difficult to propagate species; and the refinement of ratios of species to duplicate the forest structure and function.

Researchers will never have all the answers to the full suite of challenges raised by mine rehabilitation and environmental management. Alcoa's ongoing research and improvements to rehabilitation treatments suggest, however, that 10 years from now, mine restoration achievements are going to

be better than the high standard being achieved today. These refinements will also raise the level of environmental and rehabilitation performance that is expected by the community and will continue to drive ongoing improvement for the whole industry at a global level.

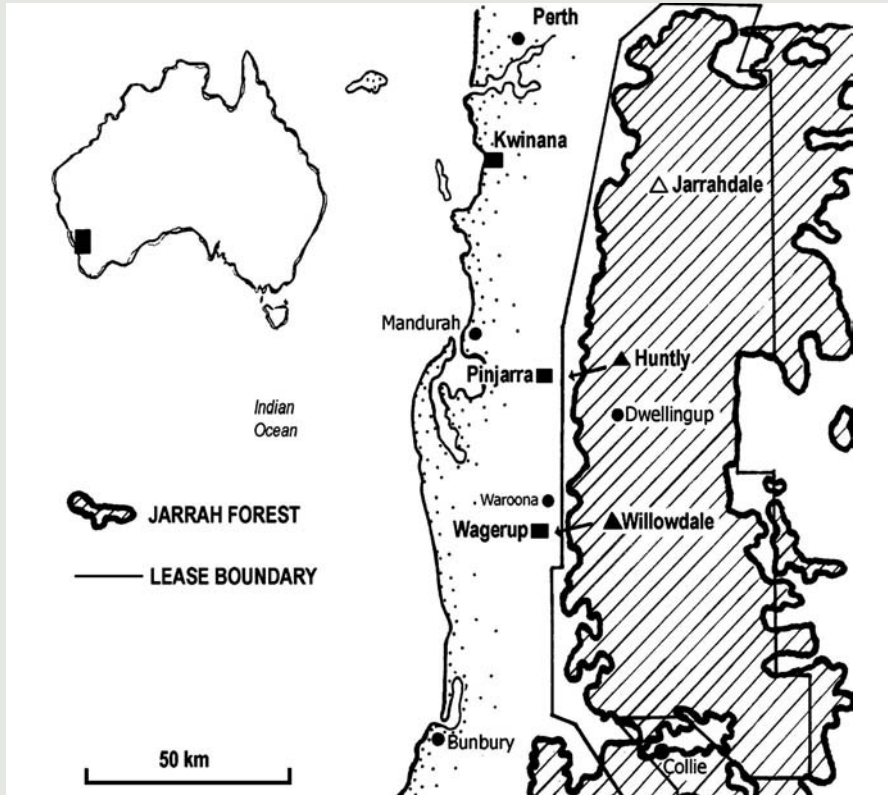


Figure 5.4 - Alcoa's operations in Western Australia



Figure 5.5 - Typical upland Jarrah forest vegetation



Advantages to addressing cumulative impacts over the lifecycle of a project can include developing relationships with local communities and regulators, and placing biodiversity values into context.

Another example where land degraded by agricultural activities can have its biodiversity values enhanced is the former Junction Reefs mine in central NSW (see LP **Biodiversity** p.17). Before mining, the site was mostly degraded farm land. Through post-mining rehabilitation **Junction Reefs** Gold Mine intended to create eucalypt woodland with a grassy understorey, characteristic of the original woodlands prior to pastoral use.



Figure 5.6 Belubula River, Junction Reefs mine

## The Community and Closure

### Community engagement

Arriving at an agreed final land use for rehabilitated mine sites involves the careful balancing of competing demands from regulators, local residents and the wider community. The aim of community and engagement and consultation on the final land use is to arrive at an agreed set of objectives for the site that will allow the company to relinquish the site in a manner that meets regulatory requirements and satisfies community expectations. Progressive rehabilitation is the life-of-mine process that enables final land use objectives to be achieved. The **Gregory Crinum** mine is located 60km north east of the rural centre of Emerald and 375km northwest of Gladstone in Queensland and consists of two mines. Operations at the Gregory open-pit mine commenced in 1979, while the nearby Crinum underground mine opened in 1995. Both mines are operated by BHP Billiton Mitsubishi Alliance (BMA). The open-pit and underground operations feed coal to a single preparation plant and rail load-out. The mines are situated in an area that has been extensively cleared for grazing and agriculture, but also contains areas of remnant vegetation, some of which have conservation value due to their scarcity. The community consultation methods used by BMA to develop its mine life plan are a good example of how existing mining operations can improve practices and involve stakeholders in helping to make key decisions on long-term land-use issues (see LP **Rehabilitation** p.6).



Figure 5.7 - Pasture and shelter trees on rehabilitated mine spoil at the Gregory mine

The rehabilitation options selected for the site need to be compatible and ideally complementary with surrounding land uses. Particular attention should be given to any opportunities to engage in or provide connecting habitat between remnant vegetation patches. There is also the opportunity to establish a broader regional rehabilitation plan, which takes into account the surrounding land-use activities. The sharing of expertise and the coordination of key activities can result in a significantly increased community benefit.

Several jurisdictions engage in landscape-level biodiversity planning, such as the regional biodiversity plans being implemented in New South Wales. Planning at this level is an effective way to manage issues such as wildlife corridors, determination of environmental water allocations and the management of threatened species and ecological communities during the assessment and approvals process.

### **Establishment of a closure committee/advisory group**

The establishment of a consultative closure committee, integrated into an overall stakeholder engagement strategy, can be a useful forum in which long-term objectives can be discussed with a wide range of stakeholders and community representatives. By involving people with a particular interest in closure issues early in the planning processes, operations can incorporate community input into the overall site plans.

These forums have shown to be a powerful means of engaging stakeholders and demonstrating to regulators that there is community support and input into the overall plan. The closure committee can also have a formal role in the sign-off process. An example is the **Beenup** mine site located in the South-West of Western Australia which closed in 1999 leaving a large expanse of deep water, a number of temporary and permanent dams and stockpiles containing mine waste consisting of cleaned sand, fine clay and varying levels of pyritic mineral.

The company was fortunate to have an active community consultative group in place at the time of the mine closure. Membership of the Beenup Consultative Group (BCG) comprised Shire representatives, landowners, and business and conservation group representatives.

To assist the community consideration of various rehabilitation concepts, BHP Billiton prepared visual impressions of preferred options. The BCG played a significant role in the selection of the preferred rehabilitation option from a number of options put forward. Following option selection BHP Billiton commenced preparation of a detailed Rehabilitation Plan for consideration by the Western Australian Government. The BCG also assisted in identifying key issues to be dealt with in the implementation process and provided a communication channel for Government to obtain feedback on aspects of the plan (see LP **Closure** p.35). Since completion of the earthworks and revegetation activities, both Government and community maintain confidence and ownership in the progress of the rehabilitation project and the community are well familiar with and speak with some authority on the principles and progress towards sustainability.



Figure 5.8 - Beenup mine, 3 years after closure

Community liaison or advisory groups established specifically for the mining project can help the operation focus its engagement program. The **Martha** mine in New Zealand provides a model example. The key outcome of the Martha mine closure process has been to provide a broader opportunity for the community to be much more proactive in working towards the long-term social, environmental, cultural and economic sustainability of the town. The committee has subsequently renamed itself Waihi Community Vision, formed various working groups to focus on particular projects, and established an organisational structure to bring community ideas to fruition (see LP **Community** p.26).

The **Argyle** Diamonds case study (see LP **Indigenous** p. 50) illustrates the benefits of the partnering approach for land rehabilitation and community capacity building. By adopting the principles of environmental co-management, the rehabilitation program has led to:

- the introduction (into the rehabilitation areas) of plant species of significant importance to local people
- the development of a small business enterprise within the two Aboriginal communities that provides seed and raise seedlings for the rehabilitation process
- employment opportunities (in horticulture-related activities) for elderly people and women with children who are not in a position to gain employment outside the community
- employment opportunities for some community members within Argyle operations.

A world class example of mine closure can be found in the Kalimantan region of Indonesia.

**MINING COMMUNITY:** West Kutai District

**LOCATION:** East Kalimantan (Borneo), Indonesia

**BRIEF DESCRIPTION:** Open pit gold mine

**AREA OF LEADING PRACTICE:** Mine Closure

**HANDBOOK(S) REFERENCE:** Closure and completion

**DESCRIPTION OF INNOVATION:**

In 2001, a partnership was established between Kelian Equatorial Mining (KEM), the West Kutai community and the Indonesia government to negotiate and agree on all aspects of decommissioning and relinquishing the Kelian gold mine following 13 years of operation. This partnership occurred during a period of civil unrest in a country undergoing enormous political and social changes with no legislation to guide the process. The outcomes from this partnership have not only informed best practice for mine closure elsewhere in the world but guided the development of closure legislation within Indonesia.

**Background**

KEM was a medium sized gold mine producing approximately 400,000 oz/ annum which operated for 13 years from 1992 to 2005. Approximately 2000 local community members (mostly alluvial miners) were relocated (some forcibly) to an adjacent town, called Tutung, prior to the commencement of construction. During peak production the mine employed approximately 2,500 employees and contractors, with a 5% expatriate workforce mainly from Australia. Post-closure land use options and ongoing maintenance activities and governance arrangements were determined via a consultation process involving government, community and mining representatives that were directed by a Mine Closure Steering Committee and four working groups over a three year period. The establishment of these closure committees occurred after the demise of the Suharto government during a period of wide spread

community unrest and political change which resulted in the devolution of significant responsibilities and power to the district government level.

### **Charter of the Steering Committee and Working Groups**

A detailed charter encompassing the roles and responsibilities of the committee members was negotiated and agreed to prior to any technical discussions. The charter also included mechanisms for reaching agreement and resolving conflicts. A secretariat was established to coordinate the meetings and documentation for the quarterly meetings. A co-ordinator and two independent facilitators were appointed to ensure that all parties were given equal opportunities to participate.

### **Closure Outcomes**

Minimising the ongoing impacts of acid rock discharges, in particular manganese (Mn) into the surrounding water catchments was the key driver for the selection of final land use options for the single pit, acid waste rock disposal areas and tailings dam areas. These areas are restricted zones, under a Protected Forest decree and the areas are patrolled and monitored by a permanent group of Community Forest Rangers. Any illegal activities or incursions such as logging, alluvial mining, farming and burning are reported to Department of Forestry and Police officials. A constructed wetland of 20hectares provides a passive treatment system for pit discharges and enables Mn levels to meet agreed discharge (2 mg/L) and ambient water quality (0.5 mg/L) standards at release points and in the Kelian River respectively.

The areas listed above which could not be rehabilitated with trees (total of 829ha) have been replaced by rehabilitating other areas of equivalent size. One area was within the Contract of Work (CoW) on the Lingau Plateau (379 ha), an area which had been previously disturbed by logging prior to the commencement of mining; the second area was away from the site in area called Bukit Suharto (450ha) which was another area which had been previously disturbed by logging and fires. The remainder of disturbed areas within the CoW (376 ha) which did not contain potentially acid forming materials and could be rehabilitated were planted with local native tree, shrub and vine species and enhanced with 10% native fruit tree mixture. These rehabilitation areas and other non-restricted areas within the CoW permit a range of activities in accordance with Protected Forest legislation including:

- Harvesting of non-wood products e.g. fruit, honey, bamboo and rattan
- Educational activities e.g. research, field visits
- Aquaculture and fishing
- Ecotourism e.g. bird watching, bush walking, swimming

During the operation of the mine, a farmer training centre (Yayasan Anum Lio - Clear Water Foundation) was established in a village approximately 30 minutes from the mine site. This centre provided both off site technical

support and on site accommodation and training to local farmers and employees wishing to improve their farming skills and practices. Upon completion of the course, each participant was assisted with seed, fertilizer and technical advice for two planting seasons. Farmer groups were also established to provide ongoing support to village farmers. Post mine closure the training centre has been converted into an Agricultural High School with boarding facilities which currently has over 100 students enrolled from surrounding villages who are completing a nationally recognized 3 year course for Senior High School.

In addition to the training centre, KEM in cooperation with local farmers also supported the establishment of approximately 450 ha of rice plantings prior to the closure of the operation. There was considered necessary due to high risk of food shortages which were predicted to occur around closure due to the dependency on mine income and decrease in rice farming which had occurred during the operation of the mine.

A post closure Endowment Trust Fund of US\$13.4M has been established in an off-shore account in Singapore which generates approximately US\$600,000 per year. This fund is used to support the ongoing activities associated with monitoring and maintenance of permanent mining-associated structures within Protected Forest and also to provide ongoing administrative and maintenance support to the Agricultural High School. It is intended that these funds will operate in perpetuity in accordance with the agreements and governance arrangements negotiated by the Mine Closure Steering Committee.



Figure 5.9 - Rehabilitation of Waste Dumps at Kelian Gold Mine

### Closure planning

The quality of mine closure planning will become apparent once the last tonne of ore is passed through the crusher and it is turned off. At this stage the key people on site will be (ideally) the closure manager and the closure team, including the planner who created the master plan, sequencing all of the activities, tasks and resources required. The key for a successful implementation is to follow the plan. By continually reviewing the plan, and rescheduling activities and resources, the deadlines can be met and, more importantly, costs controlled. This will ensure the closure tasks can be completed on time and within budget. At most sites, all infrastructure and plant will be removed, the site re-contoured and revegetated, with a small team remaining to carry out ongoing environmental monitoring and maintenance programs.

An example of good planning, team building and cooperative partnerships with the community is the closure of the **Mt McClure** gold mine in Western Australia. The Mt McClure project had several owners before it came under the control of Newmont in 2002. The mining operations consisted of a standard carbon-in-leach processing plant with multiple pits and two tailings storage facilities. In planning for the full decommissioning of the project, a risk assessment was undertaken by the closure management team with external consultants to focus on key issues and form the basis of the closure plan. This was followed by a stakeholder consultation process to further develop the plan and the creation of a process map that outlined in detail the planning steps and sequences (see LP **Closure** p.44).



Figure 5.10 - The Mt McClure site before closure

Having the right information to make the best technical and social decisions in closure planning requires the collection, assessment and management of environmental, social and economic data. It is necessary to continually review of site characterisation, baseline study information and of the risks and opportunities of closure. It is important at this step to understand the range of stakeholder requirements including community expectations for final land use, cultural and heritage values, government regulation and other legal requirements. Early identification of data gaps helps guide any research and development programs needed to demonstrate the effectiveness of unproven rehabilitation strategies. A data recording and management system will help the closure planning team in understanding the status of closure issues.

It is becoming increasingly difficult for mining companies to relinquish mine sites and “walk away” with all obligations for future maintenance and funding discharged. This is because:

- it can take considerable persistence by a company to achieve relinquishment, particularly if early rehabilitation is inadequate for the task.
- the selection of a robust and verifiable process to monitor and demonstrate completion criteria is crucial for closure.
- early establishment of verifiable completion criteria is critical to receiving acceptance and approval for relinquishment by the regulator.

An excellent case study illustrating these points is the **Bottle Creek** mine in Western Australia (see LP **Closure** p.11). The mine commenced operation in June 1988 but, due to a limited gold resource, ceased operation in November 1989. Three open-pits and waste landforms, a plant site, run-of-mine pad and two tailings storage facilities were established during the operational stage of the project. A request to release the bond and relinquish the lease was first made in 1996 and eventually finalized in 2001.



Figure 5.11 - Bottle Creek mine before and after rehabilitation



Another example of planning for closure is the **Misima** gold mine in Papua New Guinea. Misima Gold Mine commenced operation in 1987 and operated until 2004 producing 3.6 million ounces of gold. Final deconstruction and rehabilitation earthworks were completed in April 2005. The closure of a large mine site can have potentially conflicting objectives such as minimising costs of closure, maximising ongoing benefits to the local community or region, and minimising environmental liabilities from the mining operation. The achievement of such goals often requires compromises. Mine closure planning can be very challenging, particularly when socio-economic, cultural and political factors are included and further complications arise from stakeholder disputes over the actual detail of final asset disposition and final land use targets. Detailed planning for the closure of Misima Mines Limited commenced five years prior to the last ounce of gold being poured. The following outcomes were achieved (LP **Closure** p.16):

- successful deconstruction/demolition and earthworks completed as planned.
- no lost time accidents or serious injuries.
- landform use suitable for agricultural purposes.
- social opportunities created with local landholder group and government managing the hydroelectric power and water system on behalf of the community.
- local and provincial governments responsible for the health and medical centres and other infrastructure installed as part of the community development plan.



Figure 5.12 - Misima before rehabilitation



Figure 5.13 - Misima after rehabilitation

**MINE:** Misima Gold and Silver Mine

**LOCATION:** Misima Island, 200km east of Papua New Guinea (PNG)

**BRIEF DESCRIPTION:** Operation operated by Misima Mines Ltd and owned through a joint venture between Placer Dome - Misima Mines' parent company - (80%) and PNG State Company Orogen Minerals (20%). In 2006 Barrick acquired Placer Dome and its mines.

**AREA OF LEADING PRACTICE:** Development of an area's human and social capital as part of mine's operation and closure plans.

**HANDBOOK(S) REFERENCE:** Community Engagement, Working with Indigenous Communities, Mine Closure and Completion.

**DESCRIPTION OF OPERATION:** Gold and Silver mine opening in 1990, operations were completed in May 2001 with stockpile milling continuing until the closure in 2004.

**SUSTAINABILITY IMPACTS:** Misima Island was seen as being particularly vulnerable to the social impacts of large-scale mining as it had not been exposed to a large-scale development before, and had limited experience with a cash economy. Prior to the mine opening, life on the island consisted of subsistence farming and fishing. This was supplemented with cash earned from the sale of copra. For most families this was enough to buy manufactured tools and utensils, and sometimes to pay school fees.

During the mine's operation, road infrastructure was upgraded in order to transport workers from their remote villages to the mine site. Misima Mines built classrooms, medical aid posts and fresh water supply systems through a tax credit scheme that redirected a percentage of the government's revenues back to the local community. Existing trade stores expanded and new ones opened to sell workers a wider range of goods. The government built a high school on the island, enabling more local children to extend their education.

Following the mine's closure, the improvements made to the islanders' standard of living began to deteriorate. Employment opportunities were reduced and many land owners had to return to subsistence farming and fishing. Funding for the ongoing improvement and maintenance of infrastructure systems related to the mine's operation, such as roads, electricity grids and improvements to the airport, ceased as no other industries had been developed to provide alternative revenue streams. In addition, since they were provided by the mine, the PNG Government had limited capacity to maintain these projects through the national budget.

**Response of Mine Management:** Focus was placed on developing the island's human and social capital. In terms of human capital, a base had already been established by an improved education infrastructure creating a relatively high level of literacy on the island. The company also helped employees get certification in various skilled trades and professions such as accountancy, nursing and engineering. The company hired an NGO to help local leaders develop the skills needed to create strategic plans for each village and then take them to higher levels of government. Misima Mines also helped the traditional land owners where the mine was situated to get organised and initiate a trust fund with their royalty money.

Social capital meant having enough internal cohesiveness to agree upon, and work towards, common goals. On Misima, traditionally, collaborative action seldom extended beyond the clan and village levels. The challenge therefore was to have the diverse, dispersed villages and clans come together and take charge of planning their collective future. Misima Mines convened an advisory group composed of the leaders of all the stakeholders. It included churches, a women's association, a national human development NGO, an international environmental and social NGO, the landowners and four levels of government. Each time the multi-stakeholder advisory group met, it created stronger network ties among Misima's organisations.

The major problems that the advisory group faced were food security, alternative sources of cash income and public infrastructure maintenance. Misima Mines took a plot of land and started an agricultural research and training centre that experimented with various high-value, low-weight cash crops for export, such as vanilla, kava and nutmeg.

In January 2011, the PNG government announced K6 million (approximately \$2.3 million AUD) to fund detailed studies on sustainable mining activities for the people and local businesses of Misima. The aim of these studies was to develop a long-term development plan for Misima from which project funding and implementation will be based. Possible projects being investigated include cultivating cash crops, a solution that is currently having limited success in Bougainville.



Figure 5.14 - Misima Mine

Barrick Australia's Timbarra Gold Mine is located east of Tenterfield in northern NSW. Operations started in April 1998 and the mine was placed under care and maintenance in October 1999. Activities since then have focused on mine closure and associated rehabilitation and monitoring requirements. The 82 ha disturbed during the mine's operation included two pits, a spent ore stockpile, water storages and processing plant, ROM pad and haul roads. Closure planning at the Timbarra mine commenced in late 2000, when Delta Gold (the operator) decided to proceed with an independently facilitated engagement process with a wide range of stakeholders, including project opponents on the rehabilitation of the mine. The 2001 consultation process resulted in reconciliation between various conflicting groups. Instrumental to this was the mine's new owner, which had a different approach to community relations. TCFG was able to move from a state of conflict to resolution and partnership, to achieve sound mine closure (see LP **Closure** p.25). The lessons were clear:

- community and other stakeholder views, are essential in planning mine closures and should be pursued through formal processes such as community closure focus groups.
- it is important to listen to protagonists' views and address each issue.
- in many circumstances, input from environmental groups can result in better managed mines that pose less risk to the environment.
- collective knowledge can help solve or address issues of common concern.
- use of a facilitator.
- engaging in (and resourcing) conflict resolution processes rather than avoiding conflict.



Figure 5.15 - Timbarra wetland

An international and innovative example of closure planning for alternative land uses is from the Ruhr region of Germany. Former lignite mines have been converted to industrial estates, office buildings, ski runs and other uses.

**MINE:** Former lignite mines

**LOCATION:** Ruhr and Saar valleys Germany

**BRIEF DESCRIPTION:** Surface lignite mining

**AREA OF LEADING PRACTICE:** Rehabilitation; closure and completion; heritage preservation

**HANDBOOK(S) REFERENCE:** Mine Rehabilitation; Mine Closure and Completion

**DESCRIPTION OF INNOVATION:**

For more than hundred years hard coal from domestic production was a basis for industrial success in Germany. But nowadays because of relatively high production costs hard coal mining in Germany seems not to be capable of competing on the world market any more. In 2007, the German government decided to stop financial support for the coal mining industry from 2018. This led to a final mining closure program.

The German hard coal mining company RAG is supporting the restructuring process in the coal mining regions of the Ruhr and Saar valleys through the adaptive reuse of former coal fields. RAG together with state institutions and local municipalities aim at activating a sustainable development in the mining towns. Mine closure is seen as an opportunity to change both industrial and urban structures in a future-oriented way. Instead of industrial waste land, former mining areas shall become vital places, instead of an economic decline, former mining towns shall prosper.

In order to create opportunities for future-oriented long-term employment, new, innovative businesses require a good infrastructure: offices, commercial real estate, comfortable and aesthetically pleasing housing, as well as recreational areas and cultural facilities. RAG is using its real estate expertise to help the former coal mining regions progress towards this goal. Such efforts are of particular benefit to would-be owners of small- or medium-sized businesses.

The sites of former coal mines often make optimal facilities for logistics service providers with an eye on the future, although these sites must be centrally located and be within easy reach of roads, canals and railroad networks. One such site is the 9.7-acre Fürst Hardenberg Logistics Center in Dortmund, built jointly by the RAG Montan Immobilien development corporation and the logistics concern Fiege. In addition to the space occupied by the distribution center of a multinational tyre manufacturer, an additional 5.7 acres of logistics space have been leased by a textile discounter and an industrial bread bakery. Five additional logistics centers along the same lines of this 'success story' are currently in the planning stages for other projected sites in the Ruhr. Companies from other sectors such as the contracting industry, construction equipment rental, and construction machinery are also doing business on the former coal mine sites developed for reuse by RAG

Montan Immobilien. In addition, a low-cost center for installation contractors has recently gotten off to a successful start on the former site of the Werne mine. Here, space (most of it inexpensive) is leased to installation contractors such as electricians and plumbers. Other business parks have been developed at the site of the former Minister Stein and Radbod mines in Dortmund and Hamm respectively.

Besides aiding the restructuring process in the states of North Rhine-Westphalia and Saarland by promoting the establishment of new businesses on the sites of former coal mines, RAG also restores some sites to their original, natural states. In addition, RAG Deutsche Steinkohle configures spoil heaps as landscape architectural constructions. Sometimes existing spoil heaps are reconfigured, and in other cases new spoil heaps are filled according to an artist's design.

Besides business and urban development, keeping the industrial culture plays an important role for the successful restructuring process in the Ruhr Area, too. People identify their region with the industrial heritage of coal and steel industries. While these industries disappeared more and more, people became aware that there is such thing as an industrial heritage which forms the mentality of their society and a unique architectural and urban landscape. Many cultural projects and events contributed to the effort of keeping the industrial heritage by preserving outstanding industrial buildings and socio-cultural experiences:

The regional tourist project entitled "Route der Industriekultur" ("The Industrial Heritage Trail"), a 400 km circular route around the Ruhr area, opens up the region's industrial heritage to visitors. 25 so-called anchor points make up the core network of the trail, including six important museums of technical and social history, many panorama points and a series of significant workers' settlements. The trail opens access to important witnesses of 750 years of industrial history in the region, and also to the process of structural transformation which has been taking place here for several decades. The disused factory sites, many of which are under a preservation order, are not sites of nostalgia and regret. They have long been transformed into lively industrial venues and attractive centres for cultural and tourist events.

The cultural highlight of the year in the Ruhr area is surely the "ExtraSchicht (ExtraShift) Night of the Industrial Culture". Former industrial plants, active production facilities, mines and spoil heaps are skilfully turned into venues of industrial culture. Hundred thousands of people are joining this very special event during a long summer night.

The Ruhr area is an example for successful sustainable structural change in a mining area, and the old closed coal mine and now UNESCO World Heritage Zollverein Mine in Essen is its outstanding landmark - the Eiffel Tower of the Ruhr.



Fig 5.16: Former Minister Stein Coal Mine (Dortmund): Shafthead frame from 1926-1987, office building since 1999



Fig 5.17: "Stairway to Heaven" on Rheinelbe spoil heap (Gelsenkirchen)

All photographs: RAG Montan Immobilien, except No. 11: © Rupert Oberhäuser, RUHR.2010  
\*Contributed by Prof Jurgen Kretschman



## Managing the Risk of Acid Mine Drainage at Closure

### Introduction

At the time of mine closure, it should be assumed that most of the preparatory work required to protect the environment has been undertaken as part of a well-conceived Closure Plan that has been implemented throughout the operations phase. If this is not the case, it would be regarded as a failure to plan effectively and there could be a significant risk of adverse impacts with high costs being necessary to retrofit solutions at this late stage.

The former **Woodcutters** Mine near Darwin in Australia's Northern Territory involved underground and open cut mining of a large lead-zinc deposit between 1985 and 1999. At closure the residual mine waste was contained in two large tailings dams containing highly sulfidic net acid generating material, and a waste rock dump. The waste rock dump contained significant amounts of sulfidic material from the original open pit and had been open to the tropical monsoonal climate for many years (see LP **AMD** p.20).

Whilst the ultimate execution of site closure and rehabilitation activities demonstrates application of current leading practice sustainable mining principles, a number of strong lessons resulting from this case study. These are summarised below (Dowd, 2005):

- Initial optimal placement of waste material coupled with progressive rehabilitation during mining operations would have substantially reduced the closure costs.
- The closure process would have been expedited if site closure criteria had been developed and agreed in consultation with regulatory bodies and primary stakeholders during the operational life of the mine.
- Significant cost savings could have been achieved if rehabilitation activities were started prior to de-mobilisation of mine equipment and staff/contractors.



Figure 5.18 - Woodcutters mine site in 1998 prior to decommissioning and rehabilitation.



Figure 5.19 - Rehabilitated mine site in 2005, following construction of cover over the waste rock pile.

Ideally the closure phase will consist largely of the last stages of decommissioning, including demolition of infrastructure, final land-forming, revegetation and commencement of a post-closure monitoring program.

Since AMD issues can have a long lag time before they become evident, it may be necessary to monitor the success of revegetation, the effectiveness of cover systems, and any impacts on water resources for many years until good evidence of stability is on hand and sign off can be obtained from the regulator.

It should be remembered that many of the AMD management technologies are still relatively new (less than 30 years old) so there are very few long term benchmarks of success in achieving environmentally safe and stable landforms. The long term performance of closure measures needs to be demonstrated, initially through techniques such as modelling, but will always need to be verified through achievement in the field. Companies should be prepared to monitor for a long time after closure where AMD risks and potential consequences are judged to be high. Such a responsible approach will enhance the reputation of the industry and help to maintain its social licence to operate. Closure issues are dealt with comprehensively in the Leading Practice Sustainable Development handbook on “Mine Closure and Completion.”

### **Water covers**

The most effective way of restricting the exposure of reactive wastes to oxygen is to deposit them permanently under water, a technique that succeeds because of the limited amount of dissolved oxygen in water. However, water covers are only viable when an assured supply or storage of water is available.

For surface reactive waste storages, this will require valley containment in a catchment of sufficient size to maintain a water cover over the wastes, incorporating a water dam and spillway. This normally requires a net positive water balance climate, generally

limiting its application in Australia to Victoria, Tasmania and, possibly, the wet tropics. As an example, the **Benambra** Mine in East Gippsland, Victoria, was operated by Denehurst Limited as an underground base metal mine from 1992 to 1996. During operations, 927,000 tonnes of ore was processed on site and nearly 700,000 tonnes of sulfidic tailings was pumped to a nearby tailings dam. The Victorian Department of Primary Industries - Minerals and Petroleum (DPIMP) has been responsible for the site since 1998 and recently managed a successful rehabilitation program. The primary objective of site rehabilitation was to manage AMD in the tailings dam by creating a permanent water cover over the tailings and utilising passive treatment systems for long term water quality control (see LP **AMD** p.58)



Figure 5.20 - Aerial view of the Benambra tailings dam during rehabilitation works

### **General considerations for selection of treatment systems**

*Water composition.* Metals and pH are the most common targets for treatment of AMD, but the removal of major ions, such as magnesium and sulfate may also be required.

*Water volume (or flow rate).* The cost of water treatment is a function of both flow rate to be treated and the composition of the water. In many cases, the flow rate is the primary driver for sizing a treatment system, whether active or passive. Hence, efforts should be made to constrain the volume/flow rate requiring treatment, both during operations and post-closure.

*Treatment targets.* Targets for treated water quality will be site-specific and depend on a number of factors, including issues relating to protection of plant and equipment from corrosion, as well as protection of environmental values of receiving waters. Derivation of treatment targets requires consideration of the risk assessment framework detailed in ANZECC/ARMCANZ (2000), as described in Section 4.2.3. Refer to the Mt Morgan case study in LP **AMD** p.61 for an application of this approach.



Figure 5.21 - Pit water treatment plant adjacent to the AMD-filled open pit at Mt Morgan (March 2006).

## Hazardous Substances

It was once a common occurrence for closed mines to be abandoned with no regard for making the site safe with minimal environmental impacts (figure 5.22).



Figure 5.22 - Abandoned stockpile of process reagents at a closed gold mine in Fiji

It is much easier and cheaper to remove the hazardous substances while personnel and equipment are available. Cleaning up abandoned sites such as the former **Yerranderie** mine in New South Wales is a much more expensive undertaking (LP **Hazardous** p.27). Yerranderie is an historic abandoned silver-lead mining town southwest of Sydney near the World Heritage Listed Blue Mountains National Park. The site is approximately 12km upstream from Sydney's major water supply dam, Warragamba. Mining at Yerranderie occurred between 1898 and the 1930s with significant silver, lead and gold being recovered. Minimal rehabilitation occurred post mining. In 2003, intensive environmental studies found that small areas of the site had arsenic contamination levels which were potentially hazardous to human health and the surrounding environment, in particular Sydney's water supply dam. At some locations the material contained up to 25% arsenic. Existing fencing and signage surrounding these areas could only be considered a temporary solution to protect the health and safety visitors to the historic site. For these reasons, a robust longer term management solution was required. The successful project resulted in substantial rehabilitation of the Yerranderie site. Risks to the surrounding environment and Sydney's water supply were reduced and safety was improved for visitors and tourists.



Figure 5.23 - Yerranderie mine site before rehabilitation

## Final Rehabilitation

Rehabilitation is the process used to repair the impacts of mining on the environment. The long-term objectives of rehabilitation can vary from simply converting an area to a safe and stable condition, to restoring the pre-mining conditions as closely as possible to support the future sustainability of the site. Rehabilitation normally comprises the following:

- developing designs for appropriate landforms for the mine site.
- creating landforms that will behave and evolve in a predictable manner, according to the design principles established.
- establishing appropriate sustainable ecosystems.

Landform design for rehabilitation requires a holistic view of mining operations, where each operational stage and each component of the mine is part of a plan which considers the full life cycle of a mine such as planning operations and final end use of the site. This plan needs to be flexible to accommodate changes in method and technology.

Maximising planning reduces site disturbance and ensures that material such as waste rock is close to its final location. The emphasis is on gaining and analysing as much information as possible about the site. Such research has two main uses—it provides baseline data for mine planning and essential information for the rehabilitation and closure phase, when the site is being restored to an agreed post-mining use.

Key factors that need to be considered in pre-mining studies include legal requirements, climate, topography, soils and community views. Community views are clearly most important in deciding the final land use as they are the most likely site users. Their knowledge and expertise can also be invaluable in understanding aspects of the site.

The post-mining land use for an area should be defined in consultation with relevant interest groups including government departments, local government councils, non-government organisations, Traditional Owners and private landholders. The Berong mine in the Philippines indicates the importance of working with the local community's wishes in rehabilitation.

**MINE:** Berong Nickel Project (Berong Nickel Corporation).

**LOCATION:** Palawan, Region 4B, the Philippines

**BRIEF DESCRIPTION:** Surface Nickel Mining; Direct Shipping Operation

**AREA OF LEADING PRACTICE:** Sustainable Development, Progressive Rehabilitation, Re-vegetation Research Design and Practices

**HANDBOOK(S) REFERENCE:** Mine Rehabilitation

**DESCRIPTION OF INNOVATION:** Applied Rehabilitation Research, Rehabilitation Strategies

The Berong Nickel Project (BNC) is located on the Island of Palawan, the Philippines. BNC is firmly committed to best practice in environmental management, with a strong emphasis on sound social responsibility. Part of this commitment is progressive rehabilitation of the mined areas to provide sustainable outcomes.

Historically, successful revegetation of mined nickel operations has been difficult due to the highly leached nature of the lateritic soils in high rainfall regions (equatorial belt) leading to nutrient deficient soils. This is further reduced with the removal of the thin top soil layer and predominant ore body. The type of vegetation that has grown can be considered low in value in terms of ecological sustainability or economic return to the communities of the region.

To determine what would provide the possible long term solution to rehabilitation, in August 2007, BNC established a rehabilitation research project in the first mined area- Area 4. 106 - 10mx10m research plots were established on three benches to determine the best possible land forms, growing mediums and species selection taking into consideration the requirements and desires of the community post mining in terms of alternative land use.

Based on discussions with the community, it was decided that Parra Rubber would form the predominant species for the next, pilot stage of the project with a mix of Narra and Agoho. The Para rubber species and other establishment species such as Narra (high value timber used in commercial manufacturing) and Palawan Agoho (fast growing which provides a visual buffer) will be used in combination to provide greenways and buffers in the design and planting strategies. Parra Rubber was found to be the sturdiest in terms of survival and growth. The community support the establishment of Parra Rubber as it will provide a post mining income and industry. It is expected that the species will prosper with amelioration strategies such as the correct fertilizer application, soil amendments and constant management during the first 7 years of growth. It is expected that there will be a return on investment after 7 years, so management through this stage is critical.

\* contributed by: Dr Keith Halford



Figure 5.23: Aerial view of Area 4 where different crops are re-vegetated as a part of BNC's rehabilitation program. November 2007



Figure 5.24: Demonstration Billboard and Platform which shows the research design, species mix and techniques used during the research.

Understanding the site, including its drainage characteristics, is also required when designing and siting components of the mine operation. By transferring this information to mining software, the mine planners have detailed computer modelling of the original site and its drainage patterns to make decisions about restoration or alteration in its final design.

Like all computer-related technology, developments occur and become outdated quickly. Therefore, the principles involved in digitising and analysing the data are more important than the specific software packages used. End uses for the final void resulting from mining operations also require consideration and planning. Backfilling may be uneconomic in some operations but, in others, planning might avert creating any void. Safety is also crucial and creative design in conjunction with substantial obstacles and warnings are needed.

Poorly rehabilitated mines provide a difficult legacy issue for governments, communities and companies, and ultimately tarnish the reputation of the mining industry as a whole. Increasingly, as access to resources becomes tied to industry's reputation, effective closure processes and satisfactory mine rehabilitation become critical to a company's ability to develop new projects. Poor planning invariably increases the costs of rehabilitation and mine closure and decrease overall profitability. Taking a more integrated approach to mine rehabilitation, and doing it progressively, can achieve effective mine rehabilitation.



An example of leading practice in mine rehabilitation particularly regarding flora and fauna management is the **Mt Owen** coal mine, an open-pit coal mine located in the Hunter Valley of New South Wales. Mt Owen is owned by Xstrata Mt Owen (XMO), a 100% owned subsidiary of Xstrata Coal. The mine is operated by Thiess Pty Limited under a partnering agreement with XMO and is approved to produce up to 10 million tonnes of run-of-mine coal per annum for the export market until December 2025. The key components of the Mt Owen flora and fauna management program include:

- establishment and management of biodiversity conservation areas to offset mining impacts.
- progressive rehabilitation of disturbed areas to native woodland.
- implementation of specialised flora and fauna management techniques.
- comprehensive flora and fauna monitoring program.
- on-going program of native forest restoration research in conjunction with the University of Newcastle's Centre for Sustainable Ecosystem Restoration.

Mt Owen's flora and fauna management program provides protection for establishing woodland communities in rehabilitation areas and in adjoining mine-owned buffer land. Conservation areas adjoining mine rehabilitation areas are also being expanded and enhanced through proactive intervention and the restoration of scattered woodland remnants and pasture areas to provide similar vegetation communities and opportunities for movement of flora and fauna into rehabilitation areas. The short-term aim is to conserve existing flora and fauna in conservation areas through effective management, while establishing new areas that will provide a self-sustaining system in the long term. The long-term aim is to provide a self-sustaining flora and fauna conservation reserve with sufficient size to provide the necessary diversity, while providing corridor linkages to the larger vision for integrated landscapes in the Hunter Valley (see LP **Rehabilitation** p.25).

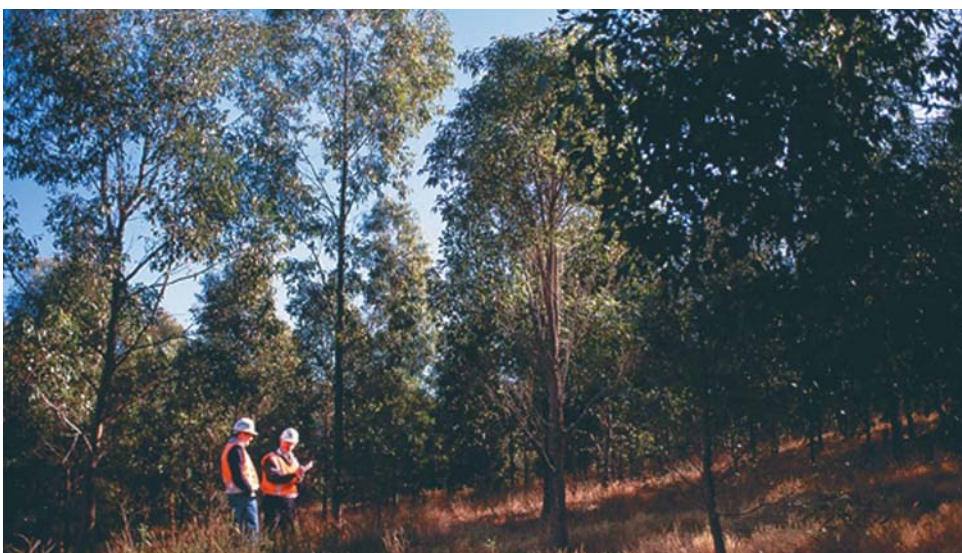


Figure 5.25 - Flora and fauna monitoring, Mt Owen

### Landform construction

In general, erosion of constructed landforms on mine sites is dominated by gullying—a direct consequence of concentration of run-off by the berms and discharge of concentrated flows onto batter slopes once the berms fail. The reasons for berm failure include inaccurate construction, tunnel erosion and overtopping due to deposition of sediment. Where erosion rates remain significant (commonly in arid areas where surface vegetation cover is too low to provide erosion control) outer batter profiles that include berms will require regular maintenance (de-silting) as long as the erosion continues, or else they will fill with sediment and overtop, causing gullying. For this reason, some sites have adopted a practice of using berms or some form of across-slope bank during initial rehabilitation, then removing the berms once vegetation has established and stabilised the slope.

Other sites have incorporated rock into the surface of outer batter slopes to reduce erosion potential and enable them to construct relatively long, high, slopes without berms. Another option is to create concave slope profiles to reduce erosion potential; usually by a factor of two or three. To develop a new approach to waste dump construction, the **Murrin Murrin** nickel mine had the erodibility of a range of wastes and topsoils assessed using both laboratory and field measurements. Using that data and long-term rainfall and climate data for the site, computer simulations of run-off and erosion were used to compare a range of options for outer batter slopes. Concave slope profiles were developed that had relatively low erosion risk, though addition of tree debris and laterite gravel was recommended for segments of the slope that the simulations showed to have highest erosion potential (see LP **Monitoring** p.45).



Figure 5.26 - Concave waste dump slope at Murrin Murrin

Surface roughness is an important consideration in rehabilitation of mine site landforms. Roughness tends to trap water and seed, and there is general acceptance that a rough surface will provide better vegetation establishment than a smooth one. However, while the creation of large surface roughness via rip lines or moonscaping may give benefits in the short term, in the longer term it may lead to increased erosion and instability of the landform. The value of surface roughness is closely linked to its persistence through time, which is largely controlled by the particle size distribution of the material in which the roughness is created.



Figure 5.27 - Moonscaping in the Pilbara (source unknown)

### Rehabilitation of quarries

Quarries and the mining of industrial minerals are not often featured in examples of leading practice however examples do exist. An international case study illustrating innovative transport options is provided by a limestone quarry in Taiwan.

**MINE:** Asia Cement Corporation Hsin-Chen Shan quarry

**LOCATION:** Hualien, Taiwan, R.O.C.

**BRIEF DESCRIPTION:** Quarry 6.5 million tonnes limestone annually on the hill side (from SL740~120m). A 300m depth vertical shaft in the quarry centre to transport crushed rock to cement plant.

**AREA OF LEADING PRACTICE:** Reclamation, innovative transport system

**HANDBOOK(S) REFERENCE:** Mine rehabilitation; mine closure and completion

**DESCRIPTION OF INNOVATION:**

Hsin-Chen Shan quarry's annual production rate is 6.5 million tonnes of limestone, and is the second largest quarry in Taiwan. Asia Cement Corp. (A.C.C.) established its cement plant at what was then relatively desolate and remote territory in Hualien, Taiwan in 1974. Neighbouring the famous Tarako Gorge National Park, it was essential that the beautiful scenery and natural resources was preserved over the life of the quarry. Over three decades, the quarry has won numerous medals and certificates for its environmental performance.

The Hsin-Chen Shan quarry terrain is very steep rising from SL120m to SL740m within only 1000m horizontal distance. In accordance to this unique topography, A.C.C. introduced a rapid shaft transporting system from Japan in 1978, the first quarry to utilize this type of shaft system in Taiwan mining history. With this successful experience, the quarry constructed the second 300m depth vertical shaft to match cement plant expansion project in 1988.

Crushed limestone is directly dumped into the vertical shaft, to eliminate the need of almost 5 kilometres of hauling by trucks. In addition to the transportation saving, the shaft system also has the advantage of reducing the dust pollution from truck fleets and preserving the original landscape amenity.

This system reduces the area of exposed benches markedly. The upper excavated out benches (the final berms) are replanted with trees immediately after mining. The combination of an underground and sealed conveying system reduces dust and noise over the length of 1.3 km conveying system from quarry to cement plant.

Evidence of recolonisation of several species including cobra and other snakes, boars and monkeys back to the once quarried area, illustrates the success of this reclamation method.

The quarry has mined out 130 million tonnes of limestone since 1974. After mining to the pit bottom, i.e., 120mSL, there will be a 30~40 hectares open ground for public use. Some visitors have expressed the view that the reclaimed final benches are even better looking than the original land surface.



The reclaimed benches in 1998  
(Photo by ACC)



The mined-out benches before  
reclamation in 1988 (Photo by ACC)

Figure 5.28 - Comparison of benches ten years apart

\* contributed by: Lawrence Hu, ACC

### **Topsoil treatments**

For soils likely to be dispersive or acid generating, the use of amendments such as gypsum or lime will be required. In some cases it may be necessary to inoculate with symbiotic micro-organisms such as nitrogen-fixers and mycorrhizae. Ripping along contour will usually be required to facilitate root penetration through compacted spoil material and to reduce seed loss.

Fertilising will also be required in most cases to replace the nutrient bank lost during vegetation removal and the mining process. It is essential that the types and methods of application of macro-nutrients and micro-nutrients are carefully planned, based on detailed soil characterisation studies and rehabilitation objectives and targets. Inorganic fertilisers are most commonly used; however, organic fertilisers such as sewage sludge or vegetation mulch can be a cost-effective alternative provided care is taken not to introduce weeds and high concentrations of metals.

Where topsoil contains a viable native seed source, it should be conserved for reuse following mining. This not only provides a cheap source of plants, but helps ensure that they establish in relative abundances that reflect pre-mining densities, and promotes establishment of species whose seed may be hard to obtain or difficult to germinate. The bauxite mine rehabilitation program conducted by **Alcoa World Alumina Australia** in the jarrah forest of south-western Australia is an excellent example of how conservation of the soil seed bank can significantly enhance the botanical diversity of the post-mining vegetation community. After vegetation is cleared, the top 150 millimetres of soil, which contains most of the soil seed bank and nutrients, is stripped prior to mining and then directly returned to a pit about to be rehabilitated, wherever possible. Research has shown that the majority of native plant species (72 per cent) on rehabilitated areas comes from seed stored in topsoil. The importance of directly returning fresh topsoil has been demonstrated by trials comparing this technique with stockpiling. These have shown that disturbance associated with direct return of topsoil results in loss of less than 50 per cent of the seed contained in the pre-mining forest seed store; by contrast, stockpiling results in losses of 80 per cent to 90 per cent. Other aspects, such as the depth of respreading topsoil, the season when the soil is handled and the timing of seeding, are also important. Seed will not survive if buried too deep, and persists better when the soil is moved during the dry season. Also, plant establishment from seeding is greater when the seed is applied to a freshly disturbed surface. Together, the combined use of fresh topsoil return, seeding, and planting of 'recalcitrant' plants have now resulted in numbers of plant species at 15 months-of-age equal to those recorded in equivalent-sized plots in unmined forest (see LP **Rehabilitation** p.40).



Figure 5.29 - Spreading topsoil at an Alcoa operation

India's mining industry is diverse and numerous minerals are mined in various terrains and climatic regimes. Iron ore mining takes place in a number of areas including the island of Goa. Despite considerable research into rehabilitation, mining companies have been slow to implement leading practices.

**MINE:** Goa Iron Ore Mines

**LOCATION:** Goa, India

**BRIEF DESCRIPTION:** Surface iron ore mining

**AREA OF LEADING PRACTICE:** Rehabilitation; closure and completion

**HANDBOOK(S) REFERENCE:** Mine rehabilitation; mine closure and completion

**DESCRIPTION OF INNOVATION:**

The iron ore mines of Goa are the most significant in India and have been mined for many decades. Until recently, little attention was paid to environmental management and mine closures. An area of around 5 ha was trialled under plantation, adopting a horti-silvicultural approach by planting fast growing species such as acacia, eucalyptus, casuarina, and cashews. Apart from these, a number of gardens have been developed by plantation of trees having high medicinal values. Irrigation is provided from rain water harvested in the existing mine pit. The entire area was stabilized in 4 years. The results have been very successful and appreciated by experts at various forums. Apart from above in collaboration with National Institute of Oceanography the company have converted one of its exhausted mine pits into a pisciculture pond in 1990. Over the years, edible fish such as Rohu, Catla & Common Carp have been cultivated in the pond. This pond has become a model of mine pit reclamation for all mining companies operating in India.



Figure 5.30 - Original mine dump



Figure 5.31 - Afforested mine dump after 7 years

\* contributed by: Professor Gurdeep Singh

## Risk Management

### **Risk at closure and post closure (legacy)**

Risks associated with closure and post-closure phases in the mine life cycle cover both economic and non-economic consequence types. These risks are long term in nature. The expectations of the local community, government, landowners, neighbouring property owners and non-government organisations (NGOs) need to be taken into account. A well-planned and managed closure process will protect the community from unintended consequences well after the mining company has left the district and will protect the reputation of the company.

Closure strategies for some mine operations may include initiatives to create enduring legacies that enhance social and/or environmental values in the vicinity of the mine and surrounding communities. In this way, the reputation of the mining company will be enhanced.

Australia hosts examples of the long term risks of older mines where closure wasn't considered until relatively recent times. The **Mount Lyell Mining and Railway Company Ltd** copper mine in Queenstown, Tasmania, resulted in more than 100 million cubic metres of mine tailings, smelter slag and topsoil being deposited into the King River and Macquarie Harbour in its 100 years of operations. Despite the cessation of tailings dumping, exposed tailings on the river banks and in the delta continually leach iron, manganese, aluminium and copper, which have contributed substantially to the metal loads in Macquarie Harbour waters and sediments. The case study in the Leading Practice **Risk** Handbook (p.17) illustrates the outcomes of using risk assessment techniques in providing guidance in the mine rehabilitation and closure process.



Figure 5.32 - The King River in SW Tasmania (Image Source: Mount Lyell Mining)



Quantitative risk assessment techniques can be used by companies to demonstrate to the community and regulators that closure issues have been identified and an appropriate security deposit can be calculated. At the **Martha gold mine** in Waihi, NZ, a quantitative risk assessment process determined that a total sum of around \$5.6 million would allow land management and maintenance responsibilities to be undertaken in perpetuity. This was considerably less than the \$100 million sought by various groups in the community.

When the bond proposal was put to the regulators, the bond structure and quantum were accepted without challenge. In the subsequent Environment Court hearing, the judge chose to round the amount up to \$6 million, and WGC posted a capitalisation bond of that amount.

The process is subject to annual review and WGC will have the opportunity to re-evaluate and modify its post-closure risk profile. There is an expectation that, over time, this focus will enable the capitalisation bond to be further reduced (see LP **Risk** p.29).



Figure 5.33 - Martha mine, Waihi, New Zealand.

### **Provisioning for mine closure**

Mining companies need to raise a provision for the anticipated expenditure to be made on mine rehabilitation and closure costs. The amount of the provision is recognised as the best estimate of the expenditure required to settle present obligations, discounted using a pre-tax discount rate that reflects current market assessments of the time value of money and those risks specific to the liability. The best estimates of expenditure are based on what a company would rationally pay to settle the obligation or transfer to a third party at the time. Companies should seek advice from financial professionals on how to address these accounting issues.

During the 1980s and 1990s, a number of mine operators in NSW and other States and Territories became insolvent and mining leases, along with the closure and rehabilitation liabilities, were passed back to the government. In many cases it was found that the security bond held by the government agencies represented only a small portion of the actual amount required to effectively close the operations to appropriate standards. Mining companies and regulators are now using a spreadsheet based security bond calculation tool to more realistically estimate the rehabilitation bond to ensure sufficient funds are available should the mine close prematurely. The tool divides the mine into separate areas that have similar rehabilitation needs for post-mining land use. These areas are called 'domains' and they typically include areas such as infrastructure, run-of-mine, tailings storage facilities, overburden and waste rock dumps, active operational areas and voids, and surface water structures. The below picture is an example of a typical mine layout showing the allocation of domains (see LP **Closure** p.31).

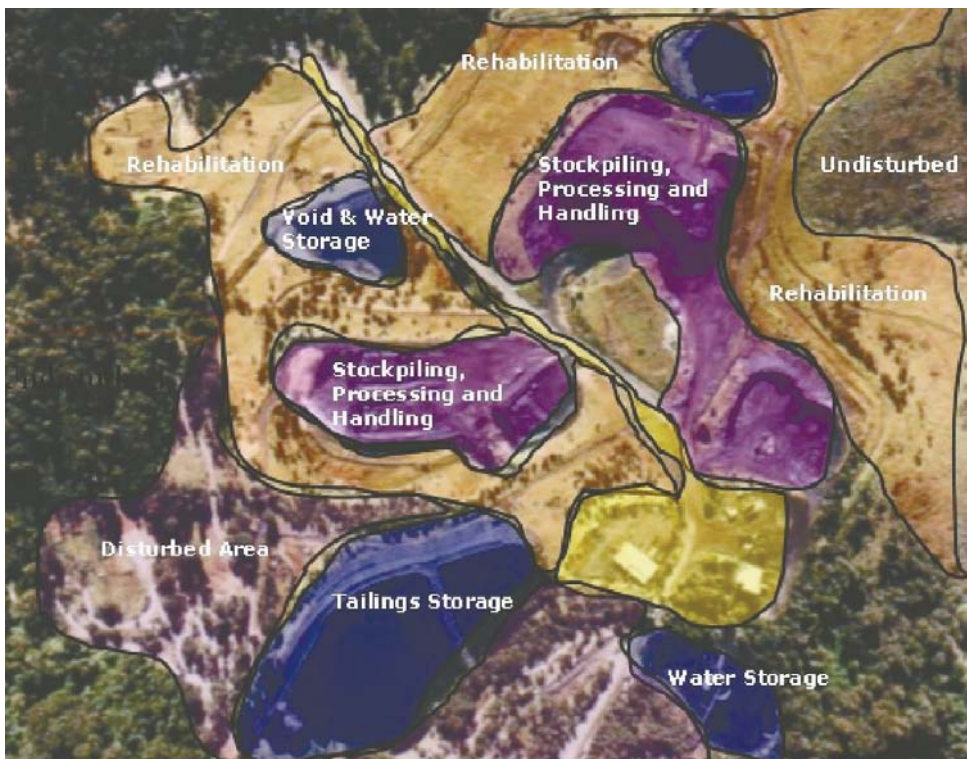


Figure 5.34 - Examples of domains for estimating rehabilitation costs

## Mine tailings rehabilitation and closure

### Tailings cover options

The rehabilitation and closure of tailings storage facilities (TSF) provide some of the biggest challenges to mine management in both coal and hard rock mining. In almost all cases a cover is required over the TSF. Possible tailings cover systems, in approximate order of increasing technical complexity and costs are (Williams, 2005 and LP **Mine Rehabilitation Handbook**, 2006):

- direct vegetation of the tailings.
- a thin layer of gravel placed directly over the tailings surface for dust mitigation.
- a vegetated, mono-layer cover, aimed at shedding rainfall runoff in a humid climate.
- a vegetated, non-shedding store/release soil cover, aimed at minimising percolation through it by the release of stored seasonal rainfall by evapo-transpiration during the dry season.
- a capillary break layer, overlain by a non-shedding, vegetated growth medium, aimed at controlling the uptake of salts into the growth medium to sustain vegetation, for application in a dry climate.
- combinations of the above.

Some of the advantages and disadvantages of the different cover systems are summarised in the following table.

COVER SYSTEM	ADVANTAGES	DISADVANTAGES
Direct vegetation	<ul style="list-style-type: none"> <li>• Low cost, if it works</li> </ul>	<ul style="list-style-type: none"> <li>• May not be sustainable due to lack of nutrients and/or fresh water</li> </ul>
Thin gravel	<ul style="list-style-type: none"> <li>• Low cost, if dust suppression is the key aim</li> </ul>	<ul style="list-style-type: none"> <li>• Will not vegetate</li> <li>• Will not limit rainfall infiltration and resulting seepage</li> </ul>
Shedding mono-layer	<ul style="list-style-type: none"> <li>• Provides a vegetated cover in a humid climate</li> </ul>	<ul style="list-style-type: none"> <li>• May deform due to consolidation of the underlying tailings, or desiccate in a dry climate, resulting in seepage of rainfall infiltration</li> </ul>
Store/release	<ul style="list-style-type: none"> <li>• May limit percolation to the underlying tailings</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a significant thickness of cover including a sealing layer at the base</li> <li>• May fail if inappropriate and unsustainable vegetation is selected</li> </ul>
Capillary break	<ul style="list-style-type: none"> <li>• May limit the uptake of salinity into the overlying growth medium allowing vegetation</li> </ul>	<ul style="list-style-type: none"> <li>• An inappropriate or too thin a capillary break material will allow salt uptake into the growth medium in an evaporative climate</li> <li>• Too thin or too coarse-grained a growth medium will not support vegetation</li> </ul>

An example of direct vegetation is provided by the former **Kidston** gold mine, located 260 km south-west of Cairns in north Queensland. A closure objective for the Kidston Gold Mine was a self-sustaining savannah woodland vegetation of native trees and introduced and native ground cover species. The 310 hectare tailings storage facility (TSF) contained approximately 68 Mt of tailings deposited between 1985 and 1996. Early revegetation trials conducted in the early-mid 1990s demonstrated the capacity of the tailings to support vegetation growth directly, without the requirement for a capping layer of soil or other cover material (LP **Tailings** p.49).



Figure 5.35 - Kidston tails before revegetation



Figure 5.36 - Kidston tails after revegetation

### **Cyanide in tailings**

Cyanide will persist in the environment long after a mine has closed. Post-closure management of this useful but hazardous substance is essential. When the closure of the tailings storage facility (TSF) at **Wiluna** gold operations was being considered in late 2000, it was decided to assess the potential environmental risk that the closure option might pose. Chemical characterisation of the tailings was undertaken to measure the risk from cyanide and heavy metals. It was concluded that some minor seepage may occur, particularly following heavy rainfall events. These seepages and the potential eluants are expected to be well below regulatory requirements. The TSF was unlikely to become acidic since it is acid consuming (see LP **Cyanide** p.64).



Figure 5.37 - Sampling the tailings at Wiluna

## Water Management

Central to a mine closure plan is the development of a progressive rehabilitation plan which ensures:

- the post-mined landscape is safe and is stable from physical, geochemical and ecological perspectives.
- the agreed sustainable post-mining land use is established and clearly defined to the satisfaction of the community and government.
- success criteria are agreed with relevant stakeholders, monitored and reported to stakeholders.
- the quality of the surrounding water resources is protected

During the closure process of the **New Wallsend** coal mine near Newcastle, NSW, one of the major technical challenges requiring the application of innovative techniques including the re-establishment of a 500-metre section of Maryland Creek. The creek was originally piped through the site for the purpose of providing for additional coal stockpiling facilities. The project represented a change to the traditional creek construction/diversion works widely used by the mining industry. The design was developed in consultation with relevant regulatory and relies on the replication of natural processes to ensure long-term stability. To date, it has been found that the riparian vegetation has become self-regenerating and negligible care and maintenance works (erosion repair) has been post closure (see LP **Water** p.76).



Figure 5.38 - Re-establishment of Maryland Creek, New Wallsend mine



## REFERENCES

AMEC 2010 *Interim Code of Conduct for Mineral Exploration in Western Australia* available at <http://www.amec.org.au/media/docs/AMEC-CodeOfConduct%28final%29.pdf>

ATSDR 1997, *Toxicological Profile for Cyanide*, Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, Atlanta, Georgia, USA, p. 46.

Australian Government *Australia State of the Environment 2006*, Independent report to the Australian Government Minister for the Environment and Heritage, Canberra.

Auty, R.M. and Mikesell, R.F., 1998, *Sustainable Development in Mineral Economies*. Clarendon Press, Oxford.

Ballantyne, B. and TC Marrs (eds.), 1987, *'Toxicology of cyanides', Clinical and Experimental Toxicology of Cyanides*, Wright Publishers, Bristol, UK 1987.

Batley, G.E., Humphrey, C.L., Apte, S.C., and Stauber, J.L., 2003, *A Practical Guide to the Application of the ANZECC/ARMCANZ Water Quality Guidelines for the Mining Industry*, Australian Centre for Mining Environmental Research, Brisbane, Queensland.

Clarke T, 2008, Barnett: *'Esperance lead pollution still a major concern.'* WA Today, 10 November 2008. Accessed at <http://www.watoday.com.au/wa-news/barnett-esperance-lead-pollution-still-a-major-concern-20081110-5lg9.html> on 30 August 2009.

Department of Environment, Water, Heritage and the Arts (DEWHA), *Intergovernmental Agreement on the Environment*. 1992

Den Dryver, J., *Relevance of International Code on Cyanide Management within Newmont Australia*. Sustainable Development Conference, 10-15 November 2002, Minerals Council of Australia, Canberra.

Department of Industry, Tourism and Resources, *Water Reform and Industry—Implications of recent water initiatives for the minerals, petroleum, energy, pulp and paper industries*. Prepared by ACIL Tasman (2007)  
<[http://www.nwc.gov.au/nwi/docs/Water\\_Reform\\_and\\_Industry.pdf](http://www.nwc.gov.au/nwi/docs/Water_Reform_and_Industry.pdf)>

Department of Resources, Energy and Tourism 2006-2009 *Leading Practice Sustainable Development Program for the Mining Industry Handbooks*: Airborne Contaminants, Noise and Vibration; Biodiversity Management; Community Engagement and Development; Cyanide Management; Evaluating Performance: Monitoring and Auditing; Hazardous Materials Management; Managing Acid and Metalliferous Drainage; Mine Closure and Completion; Mine Rehabilitation; Risk Management; Stewardship; Tailings Management; Water Management; Working with Indigenous Communities available at [http://www.ret.gov.au/resources/resources\\_programs/lpsdpmining/pages/default.aspx](http://www.ret.gov.au/resources/resources_programs/lpsdpmining/pages/default.aspx)

Department of Resources, Energy and Tourism, 2008, *Evaluation and Review of the Leading Practice Sustainable Development Program for the Mining Industry*. 2008, SKM

Donato, DB & Smith, GB., 2007, *Summary of Findings : ACMER Project 58, Sunrise Dam gold mine sponsor's report*, AngloGold Ashanti Australia, Donato Environmental Services SA, pp. 27.

Dowd, 2005, *The Business Case for Prevention of Acid Drainage*. Keynote speech from 23 August 2005, ACMER workshop, [http://www.inap.com.au/public\\_downloads/Whats\\_New/PD\\_Keynote\\_Speech\\_23\\_August\\_2005.doc](http://www.inap.com.au/public_downloads/Whats_New/PD_Keynote_Speech_23_August_2005.doc)

Environment Australia 1995, *Best Practice Environmental Management in Mining Series—Onshore Minerals and Petroleum Exploration*. Available at <http://www.ret.gov.au/resources/Documents/LPSDP/BPEMOnshoreExp.pdf>

Environment Australia 1998, *Best Practice Environmental Management in Mining Series—Cyanide Management*. Available at <http://www.ret.gov.au/resources/Documents/LPSDP/BPEMCyanide.pdf>

Environmental Protection Authority (WA), 2004a, *Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act 1986) No. 51*. Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia.

Environmental Protection Authority (WA), 2004b, *Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act 1986) No. 56*. Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia.

Harvey, B and Brereton, D., 2005, *Emerging models of community engagement in the Australian minerals industry*, International Conference on Engaging Communities, Brisbane.

Hilson, G., Basu, A.J., 2003, *Devising indicators of sustainable development for the mining and minerals industry: an analysis of critical background issues*. International Journal of Sustainable Development and World Ecology 10 (4), 319e332.

ICMM 2003 *Sustainable Development Framework* available at <http://www.icmm.com/our-work/sustainable-development-framework/10-principles>



Laurence, D.C. ,2011, "Establishing a Sustainable Mining Operation–An Overview"  
Journal of Cleaner Production Vol. 19, Issue 2-3, Jan/Feb 2011 Elsevier Science Ltd

Laurence, D.C., 2005, *Safety Rules and Regulations on Mine Sites–The Problem and a Solution*. Journal of Safety Research. Volume 36, Issue 1, p. 39-50 ISSN 00224375.

Laurence, D.C. 2006, "Why Do Mines Close?" *Proceedings First International Seminar on Mine Closure*. Australian Centre for Geomechanics, Perth, Pages 83-94. ISBN 0 975675664.

Minerals Council of Australia, 2004, *Enduring Value: The Australian Minerals Industry Framework for Sustainable Development*, October 2004. Canberra, Australia.

Olsson, P, Folke, C & Berkes, F, 2004, 'Adaptive co-management for building resilience in social-ecological systems', *Environmental management*, vol. 34, no. 1, pp. 75-90.

Rajaram, V., Dutta, S., Parameswaran, K., 2005, *Sustainable Mining Practices: A Global Perspective*. Taylor and Francis Group, London UK. ISBN 90 5809 689 0.

Richardson, ML (ed.), 1992, *The Dictionary of Substances and their Effects*, Royal Society of Chemistry, UK, pp. 716-718.

Rudenno, V. 1999, *Mining Valuation Handbook* Wiley ISBN 9780731409839.

Safe M, 2009, Bad vibrations, *The Australian* 26 January 2009.

Scott, P.A., Eastwood, G., Johnston, G. and Carville, D., 2000, *Early Exploration and Pre-feasibility Drilling Data for the Prediction of Acid Mine Drainage for Waste Rock*, Proceedings of the Third Australian Acid Mine Drainage Workshop, Townsville.

van Berkel, R., 2002, *Application of cleaner production principles and tools for eco-efficient minerals processing, proceedings Green Processing 2002: International Conference on the Sustainable Processing of Minerals*, Australian Institute of Mining and Metallurgy, Cairns.

WBCSD, 2000, *Eco-efficiency: creating more value with less impact*, World Business Council for Sustainable Development, Geneva, p.32.

Williams, D.J. ,2005, Chapter 17: *Placing covers on soft tailings, Ground Improvement-Case Histories*, 491-512. Eds B. Indraratna and J. Chu. Elsevier.



## GLOSSARY AND ACRONYMS

### **Abandoned mine or site**

An area formerly used for mining or mineral processing, where closure is incomplete and for which the title holder still exists.

### **Aboriginal Land Council**

Aboriginal Land Councils are the peak bodies in Indigenous affairs within Australian states and the Northern Territory.

### **Acid**

A measure of hydrogen ion (H<sup>+</sup>) concentration; generally expressed as pH. Acid is not equivalent to acidity (see definition below).

### **Acid and metalliferous drainage**

Acid and metalliferous drainage, traditionally referred to as “acid mine drainage” or “acid rock drainage”, includes both acidic, metalliferous drainage, and near-neutral but metalliferous drainage.

### **Acid mine drainage**

Acidic drainage from mine wastes resulting from the oxidation of sulphides such as pyrite.

### **Acid-based accounting**

An analytical technique that determines the maximum potential acidity that can be generated by oxidation of sulphides compared with the neutralisation potential of rock or tailings. It is also used to predict the potential of the material to be acid-producing, neutral or alkali-producing.

### **Acidity**

A measure of hydrogen ion (H<sup>+</sup>) concentration and mineral (latent) acidity; generally expressed as mg/L CaCO<sub>3</sub> equivalent. Measured by titration in a laboratory or estimated from pH and water quality data.

### **Active treatment**

Process in which chemicals or natural materials are added to AMD to improve water quality. Operator control can vary from relatively simple batch treatment to a sophisticated computerised treatment plant with multiple additives and detailed process monitoring and control. Active treatment involves regular reagent and labour inputs for continued operation, compared with passive treatment (see below) that only requires occasional maintenance. Active treatment systems can be engineered to deal with any acidity, flow rate and acidity load.

### **Adaptive management**

A systemic process for continually improving management policies and practices by learning from the outcomes of operational programs. The ICMM Good Practice Guidance on Mining and Biodiversity refers to adaptive management as ‘do-monitor-evaluate-revise’.

**Alkaline cover**

A soil cover (eg. water shedding or store-and-release cover (defined below)) that has an “alkalinity generating” component deployed above, within or at the base of the cover. The aim is to minimise infiltration and ensure that any water that migrates through the cover contains substantial alkalinity

**Analogue**

Unmined feature against which a mined feature may be compared.

**ANC**

Acid Neutralising Capacity, expressed as kg H<sub>2</sub>SO<sub>4</sub> equivalent per tonne.

**Angle of repose**

The maximum angle from horizontal at which a given material will rest on a given surface without sliding or rolling.

**APP**

Acid Producing Potential, expressed as kg H<sub>2</sub>SO<sub>4</sub> per tonne.

**AS/NZS 4360 Risk Management Standard**

The Australian and New Zealand 4360 Risk Management Standard is a generic framework for establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk.

**Backfilling**

Refilling of an excavation or void.

**Barren pond**

Storage pond for solution from which gold has been extracted.

**Basal layer**

The soil or rock foundation layer at the base of an engineered structure.

**Baseline studies**

Studies undertaken to describe the conditions that exist before an action is taken.

**Batter slope**

Recessing or sloping a wall back in successive courses.

**Benthic**

Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).

**Berm**

A horizontal shelf or ledge built into an embankment or sloping wall to break the continuity of the otherwise long slope for the purpose of strengthening and increasing the stability of the slope, to catch or arrest slope slough material, or to control the flow of runoff water and erosion.

**Biodiversity**

The variety of life on our planet, measurable as the variety within species, between species, and the variety of ecosystems. See Section 2.1 of this booklet for a full definition.

**Biodiversity offsets**

Conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure no net loss of biodiversity.

**Block model**

A three-dimensional model of the distribution of ore and waste materials with different geochemical properties (metalliferous mines).

**Bund**

An earthen retaining wall. A low embankment often constructed around potential spillage areas to reduce the risk of environmental contamination. It is important these structures can retain the volume of any potential spillage.

**Capillary break**

A layer of coarse material placed with a limited capillary rise between finer-textured materials to prevent the vertical movement of water (and associated salts) by surface tension from the lower, finer-textured material into the upper finer-textured material.

**Care and maintenance (temporary closure)**

Phase following temporary cessation of operations when infrastructure remains intact and the site continues to be managed.

**Cemented paste tailings**

Tailings with the consistency of a paste, to which cement is added to enhance strength for underground stope backfill.

**Centreline method, construction or raising**

Construction of the tailings containment walls above a fixed crest alignment, using waste rock, borrow materials or tailings.

**Central thickened discharge**

The discharge of thickened tailings from one or more towers or discharges located within the body of the facility, with only a nominal perimeter wall where any supernatant water is recovered.

**Centrifuge**

A device that dewateres a slurry through the application of centrifugal force against a drainage surface.

**CIL**

Carbon-in-leach. A process used to recover gold into activated carbon during the agitation leach process.

**CIP**

Carbon-in-pulp. A similar metallurgical process to CIL used to recover gold.

**Cleaner Production**

The continuous application of an integrated preventive environmental strategy to processes, products, and services in ways that increase efficiency and reduce risks to humans and the environment. By reducing pollution and waste at the source, and striving for continuous improvement, cleaner production can bring financial as well as environmental benefits.

**Closure**

A whole of mine life process which typically culminates in tenement relinquishment. It includes decommissioning and rehabilitation.

**Coarse (coal) reject**

The coarse fraction of the mineral matter removed from run-of-mine coal by washing.

**Co-disposal**

The combined disposal of coarse and fine-grained mine wastes, such as the pumped co-disposal of coal washery wastes.

**Community**

There are many ways to define 'community'. In mining industry terms, community is generally applied to the inhabitants of immediate and surrounding areas who are affected by a company's activities. 'Local community' usually indicates a community in which operations are located and may include Indigenous and non-Indigenous people.

**Community engagement**

Deliberate and strategic liaison with communities and individuals that reside in close proximity to, and are potentially affected by, mining activity. Effective engagement typically involves identifying and prioritising stakeholders, conducting dialogue to understand their interest in an issue and any concerns they may have, exploring with them ways to address these issues, and providing feedback on actions taken.

**Community impact**

Detrimental harm to the neighbouring community.

**Completion criteria**

An agreed standard or level of performance which demonstrates successful closure of the site.

**Consolidation**

The expulsion of water from settled slurry.

**Consultation**

The act of providing information or advice on, and seeking responses to, an actual or proposed event, activity or process.

**Containment wall**

A structure providing outer encapsulation for tailings.

**Contaminated site**

A site at which hazardous substances occur at concentrations above background levels and where assessment shows it poses, or is likely to pose, an immediate or long-term hazard to human health or the environment.

**Country**

When used in the context 'living on country' or 'speaking for country' refers to the area of Australia that a particular person or group of Indigenous people have a traditional connection and a sense of belonging to.

**Cultural heritage**

Cultural heritage encompasses the qualities and attributes of places that have aesthetic, historic, scientific or social value for past, present or future generations. These values may be seen in a place's physical features, but importantly can also be intangible qualities such as peoples associations with, or feelings for a place.

**Cyanide forms**

These are complexes of cyanide with gold, mercury, cobalt, and iron that are very stable even under mildly acidic conditions. Both ferrocyanides and ferricyanides decompose to release free cyanide when exposed to direct ultraviolet light in aqueous solutions. This decomposition process is reversed in the dark. The stability of cyanide salts and complexes is pH dependent and, therefore, their toxicities can vary.

**Decant or supernatant water**

Body of process water that has separated from the tailings solids (supernatant water) in the tailings storage facility, plus any rainfall runoff collected on the facility.

**Decommissioning**

The process that begins near, or at, the cessation of mineral production and ends with removal of all unwanted infrastructure and services.

**Deep bed thickener**

A thickener relying on a lifting action to minimise the likelihood of "bogging" and allow a deep bed of slurry to be thickened and delivered on demand.

**Deoxygenation**

The act or operation of depriving of oxygen.

**Desiccation**

Drying, shrinkage and cracking of the tailings surface by solar evaporation.

**Dewatering**

Removal of water from a slurry by thickening, filtration or centrifuging.

**Dewatering in situ**

Drain-down of deposited wet tailings as they undergo sedimentation, consolidation and desiccation.

**Dispersive soil**

Soils that are structurally unstable and disperse in water into basic particles (such as sand, silt and clay). Dispersive soils tend to be highly erodible and present problems for successfully managing earthworks.

**Diversion task:**

A diversion task manages raw water to facilitate mining and processing operations. A diversion task does not connect with site stores. It does not transform raw water into worked water. It displaces raw water, with some losses.

**Down Valley Discharge**

Discharge of thickened tailings down a valley towards a containment wall, located at the head of a catchment.

**Downstream method, construction or raising**

Construction of the tailings containment walls in a downstream direction, generally using waste rock or borrow materials.

**Downstream or outer face**

External perimeter of a tailings storage facility exposed to the environment.

**Dreamtime**

Also called The Dreaming, it is the central, unifying theme in Aboriginal culture. Australian Aborigines are thought to have the oldest continuously maintained cultural history on Earth (50 000 years or more); the Dreamtime explains the origins and culture of the land and of its people and is, in Australian Aboriginal lore, the mystical past when spirit gods were believed to inhabit the earth.

**Eco-efficiency**

Eco-efficiency is “reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth’s carrying capacity”.

**Eco-system**

A system whose members benefit from each other’s participation via symbiotic relationships (positive sum relations). It is a term that originated from biology and refers to self-sustaining systems.

**Ecosystem Function Analysis (EFA)**

A procedure used by some mines to assess ecosystem function and recovery following disturbance. The three components of EFA are Landscape Function Analysis, Vegetation Dynamics and Habitat Complexity.

**Embankment**

A term describing a tailings or water containment wall.

**Encapsulation**

Surrounding a reactive waste by benign materials that isolate the reactive waste material from oxygen ingress and/or water flow.

**End-dumping**

The process of dumping material from the back of a dump truck. Overburden piles are constructed by backing a dump truck on the top surface of a pile to the edge of the pile, and end-dumping the waste rock over the side of the pile.

**Endemic species**

Native plant or animal restricted to a specific locality or geographic region.

**Enduring Value**

Enduring Value is the Australian Minerals Industry Framework for Sustainable Development. Established by the Minerals Council of Australia, it aligns with global industry initiatives and, in particular, provides critical guidance on the International Council on Mining and Metals’ (ICMM) Sustainable Development Framework Principles and their application at the operational level. For further information refer to the Minerals Council of Australia web site: [www.minerals.org.au](http://www.minerals.org.au).

**Engagement**

At its simplest, engagement is communicating effectively with the people who affect, and are affected by, a company's activities (its stakeholders). A good engagement process typically involves identifying and prioritising stakeholders, conducting a dialogue with them to understand their interest in an issue and any concerns they may have, exploring with them ways to address these issues, and providing feedback to stakeholders on actions taken. At a more complex level, engagement is a means of negotiating agreed outcomes over issues of concern or mutual interest.

**Enterprise-wide risk**

The overarching risk management framework that defines the framework scope of risk types and the key risk management processes implemented across the whole organisation to manage risk in a holistic and systematic way.

**Entrainment:**

The water that is contained in the rock or coal after it is processed. The moisture content after processing is usually greater than before processing.

**Environmental impact**

Detrimental harm to the environment.

**Environmental indicator**

A parameter (or a value derived from a parameter) which provides information about an environmental phenomenon

**Environmental Management System (EMS)**

A tool for managing an organisation's impact on the environment. It provides a structured approach to planning and implementing environmental protection measures.

**Evaporation**

The process by which water is converted from liquid to vapour and is lost to the atmosphere.

**Event tree analysis**

A technique used to describe the range and sequence of possible outcomes of an event.

**Exploration**

The search for mineral deposits up to discovery and includes the delineation of the deposit by means of drilling and sampling.

**Extended producer responsibility**

The application of responsibility for managing the environmental and social impacts of a good at its end-of-life to the producer (or brand name) of the good.

**Factor of safety**

The factor by which the resisting actions exceed the disturbing actions.

**Failure modes**

The mechanisms by which a tailings storage facility may fail.

**Filter cake**

The semi-solid structure formed on the application of pressure during filtration of a slurry.



**Final void**

The remnant open pit left at mine closure.

**Fine (coal) reject**

The fine fraction of the mineral matter removed from run-of-mine coal by washing.

**Flocculants**

Chemical additives that facilitate the agglomeration of tailings particles to aid and speed up their sedimentation and consolidation.

**Fly-in, fly-out**

Fly-in, fly-out operations utilise a moveable workforce, where employees reside some distance from the operation and are flown to site to work for a period of time and then flown out again.

**Footprint**

The surface area covered by the mine and its associated infrastructure.

**Freeboard**

The elevation of the crest of the containment wall above the tailings surface, which provides for the storage of storm water.

**Functional ecosystem**

An ecosystem that is stable (not subject to high rates of erosion), effective in retaining water and nutrients and is self-sustaining.

**Geomembrane**

A manufactured low permeability sheet such as high density polyethylene (HDPE).

**Geotechnical**

The engineering of the ground and or earthen structures.

**Gradual risk**

A gradual risk event occurs over a long period of time and is representative of many types of pollution of the environment. For example slow leaks from hydrocarbon containment, acid seepage or emissions to the atmosphere.

**Groundwater**

Water beneath the earth's surface that fills pores between porous media—such as soil, rock, coal, and sand—usually forming aquifers. In some jurisdictions the depth below the soil surface is also used to define groundwater (although different states may use different depths).

**Hazard**

A hazard is a source of potential harm.

**Heap leach**

Using chemicals to dissolve minerals or metals out of an ore heap. During heap leaching of gold, a cyanide solution percolates through crushed ore heaped on an impervious pad or base pads.

**High rate thickener**

A thickener through which a slurry is passed at a high rate, with limited residence time, allowing a high flocculant dose.

**Hydraulic conductivity**

Otherwise known as (water) permeability; a measure of the ability of a porous material to pass water.

**Hydraulic backfill**

Fill that is placed as a fluid.

**Hydroseeding**

Spraying a mixture of paper or straw mulch, containing seed, fertiliser and a binding agent, onto a slope which is too steep or inaccessible for conventional seeding techniques.

**Inactive site**

A mining or mineral processing area which is currently not being operated but which is still held under some form of title. Frequently such sites are referred to as being under 'care and maintenance'.

**Indigenous Land Use Agreements (ILUA)**

ILUAs are used to negotiate with Indigenous people with native title interests regarding the doing of acts affecting native title. Under the Native Title Act, a registered ILUA is legally binding on all people who hold native title over the agreement area, whether or not they are party to the agreement.

**Interested party**

A person, group or organisation with an interest in the process of, or outcome of, mine closure.

**Key in**

Construction of a back-filled trench to reduce seepage or improve the stability of an earthen embankment.

**Kinetic testing**

Dynamic testing of acid generation, including the effect of reaction time.

**Lag time**

Time delay between the disturbance or exposure of acid generating materials and the onset of acidic drainage.

**Landholder**

The owner of freehold land, the holder of leasehold land, or any person or body who occupies or has accrued rights in freehold or leasehold land.

**Leading practice**

Best available current practice promoting sustainable development.

**Licence-to-operate**

The permission government gives to the mining industry to mine and produce minerals from specific operations through formal legislative and legal agreements.

**Life Cycle**

A company needs to examine each step in the life cycle of a product, including those that are easily overlooked, such as the fate of the product after its useful life. These steps will typically include the extracting and processing of materials; manufacturing, transportation and distribution; use, reuse, maintenance; recycling and final disposal.

**Liner**

A low permeability base comprising compacted clay, and/or a geomembrane or geosynthetic (clay in a geotextile “sandwich”).

**Local provenance**

Plants whose native origin is close to that where they are going to be planted (for example in the same local area).

**Low grade ore stockpile**

Material that has been mined and stockpiled, with sufficient value to warrant processing, either when blended with higher-grade rock or after higher-grade ore is exhausted, but often left as ‘waste’.

**Materials stewardship**

Materials stewardship overarches the stewardship approach since it applies to resources, processes and products and, therefore, covers the full life cycle. It describes an integrated program of actions aimed at ensuring that all materials, processes, goods and/or services that are produced, consumed and disposed along the value chain are done so in a socially and environmentally responsible manner.

**Moonscaping**

A technique using dozer blades to scallop a pattern which helps prevent erosion.

**Monte Carlo simulation**

A method for iteratively evaluating a deterministic model using sets of random numbers as inputs. The method is often used when the model is complex, nonlinear, or involves more than just a couple uncertain parameters.

**Native Title**

In the 1992 Mabo decision, the High Court of Australia recognised that the Meriam people of the Torres Strait held native title over part of their traditional lands. The High Court found that the common law of Australia recognises rights and interests to land held by Aboriginal and Torres Strait Islander people under their traditional laws and customs.

**Natural analogue**

An unmined landform to which a mined landform may be compared to develop sustainable post-mining landforms.

**NAG**

Net Acid Generation test, also referred to as “single addition NAG test”. Peroxide is used to oxidise any sulfides in a sample, then any acid generated during oxidation may be partially or completely consumed by neutralising components in the sample. Any remaining acidity is expressed as kg H<sub>2</sub>SO<sub>4</sub> per tonne. A “sequential NAG test” involves a series of NAG tests on a sample. This may be required if a sample cannot be fully oxidised using the conventional NAG test.

**NAPP**

Net Acid Producing Potential, expressed as kg H<sub>2</sub>SO<sub>4</sub> per tonne. Calculated by subtracting acid neutralising capacity (ANC) from acid producing potential (APP).

**NPI**

National Pollutant Inventory.

**Net present value (NPV)**

Net present value or NVP is a measurement used to decide whether to proceed with an investment. It is calculated by adding together all the expected benefits and subtracting all the expected costs from the investment, now and in the future. If the NVP is negative, then the investment cannot be justified by the expected returns. If the NVP is positive, then it can be justified financially.

**Non-government organisations (NGOs)**

A non-profit group or association organised outside institutionalised political structures to realise particular social objectives (such as environmental protection) or serve particular constituencies (such as Indigenous peoples). NGO activities range from research, information distribution, training, local organisation, and community service to legal advocacy, lobbying for legislative change, and civil disobedience. NGOs range in size from small groups within a particular community to huge membership groups with a national or international scope.

**Operational risk**

Operational risks are those risks that are focused on addressing aspects of an operation which may be more systemic to the mining process and the day-to-day operation of a mine.

**Orphan site**

An abandoned mine for which a responsible party no longer exists or can be located.

**Outrage**

Outrage is anger and resentment aroused by injury or insult.

**Overtopping**

Water or tailings slurry breaching the top of the containment structure.

**PM10**

Particulate matter less than 10 microns in diameter

**PM2.5**

Particulate matter less than 2.5 microns in diameter

**Paddock-dumping**

Truck dumping over a flat surface.

**Passive treatment**

Passive treatment systems are best suited to AMD with low Acidity (<800 mg CaCO<sub>3</sub>/L), low flow rates (<50 L/s) and therefore low Acidity Loads (<100-150 kg CaCO<sub>3</sub>/day). Also see "Active treatment".

**Paste tailings**

Tailings slurry thickened to a paste consistency, with a high yield stress, and reduced slump and bleed water. Cement is added to produce cemented paste tailings backfill for underground mine stopes.

**Percolation**

The seepage of infiltration to the receiving environment.

**Personal safety**

Preserving the safety of mine site personnel and the general public in the face of mine site risks of injury.

**Piezometers**

Sensors used to monitor groundwater mounding beneath and surrounding a tailings storage facility.

**Pioneer species**

The first species to colonise an area of disturbance.

**Piping**

The formation of an erosion tunnel through an earthen structure due to the induced flow of water through it.

**Post-mining land use**

Term used to describe a land use which occurs after the cessation of mining operations.

**Power station or fly ash**

A by-product of the production of electricity from coal-fired power stations.

**PPV**

Peak particle velocity (ppv) is a measure of ground vibration magnitude and is the maximum instantaneous particle velocity at a point during a given time interval in  $\text{mms}^{-1}$ . (Peak particle velocity can be taken as the vector sum of the three component particle velocities in mutually perpendicular directions)

**Precautionary principle**

If 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.

**Probability costing**

Estimates of value (cost or benefit) that account for the likelihood of occurrence and the range of values of the outcome - values are expressed through a statistical analysis (e.g. Monte Carlo simulation) using a statistical distribution over the range of possible values accounting for the probability and timing of the event occurring.

**Process stewardship**

Involves a program of actions focused on ensuring that processes, such as beneficiation, flocculation, crushing, gravimetric separation, and others that are used to produce ores, concentrates and other mineral products are undertaken in a socially and environmentally responsible manner.

**Product stewardship**

This is perhaps the best known form of stewardship, is a product-centred approach to protecting human health and the environment. It aims to minimise the net environmental impact from product use, including its manufacturing; distribution; servicing; and end-of-life management; through product and product system design as well as regulatory controls and provision of appropriate management information to all who come in contact. This is a product-focused approach that attempts to build engagement throughout the value chain, including with customers. Under a broader scheme of Product Responsibility, or Stewardship, other stakeholders (partners) who would share responsibility include consumers (responsible use and disposal of the material) and recyclers or waste managers who deal with products at end of life.

**Propagule**

Any structure having the capacity to give rise to a new plant, whether through sexual or asexual (vegetative) reproduction. This includes seeds, spores, and any part of the vegetative body capable of independent growth if detached from the parent.

**Provision**

A financial accrual based on a cost estimate of the closure activities.

**Public health risk**

The likelihood of harm to public health.

**Quality assurance**

Ensuring the quality of a process, for example construction, including the documentation and reporting of test work.

**Raw water**

Water that has not passed through a site water task, such as rainfall

**Reactive waste**

Waste that reacts on exposure to oxygen.

**Reagent recovery**

Capture of processing chemicals from the tailings stream.

**Recalcitrant species**

Species that are difficult to re-establish.

**Receiving environment**

The receiving environment that surrounds and is downstream (or down aquifer) of an operation's lease.

**Reclamation**

Treatment of previously degraded and often contaminated land to achieve a useful purpose. Often used outside Australia instead of rehabilitation.

**Red mud residue**

A by-product of the production of alumina from bauxite.

**Rehabilitation**

The rendering of a safe, stable and non-polluting tailings storage facility in the long-term, taking into account beneficial uses of the site and surrounding land.

**Relinquishment**

Formal approval by the relevant regulating authority indicating that the completion criteria for the mine have been met to the satisfaction of the authority.

**Remediation**

To clean-up or mitigate contaminated soil or water.

**Remnant vegetation**

Native vegetation remaining after widespread clearing has taken place.

**Resource stewardship**

Involves a program of actions to ensure that resource inputs to a process, including the minerals, water, chemicals, and energy are being used for their most efficient and appropriate use.

**Responsible authority**

Any government body empowered to approve activities associated with the closure process.

**Rip-rap**

A loose assemblage of broken rock placed to protect soil from the forces of erosion or from movement due to excess hydrostatic forces.

**Riparian**

Pertaining to, or situated on, the bank of a body of water, especially a watercourse such as a river.

**Risk**

Risk is the chance of something happening that will have an impact on objectives. It is often specified in terms of an event or circumstance and the consequences that may flow from it.

**Risk analysis**

Risk analysis is the systematic process used to understand the nature of, and to deduce the level of, risk. It provides the basis for risk evaluation and decisions about risk treatment.

**Risk control**

A risk control is an existing process, policy, device, practice or other action that acts to minimise negative risk or enhance positive opportunities.

**Risk criteria**

Risk Criteria are the terms of reference by which the significance of a risk is assessed.

**Risk evaluation**

Risk evaluation is the process of comparing the level of risk against risk criteria.

**Risk management**

Risk management is the process and structures that are directed towards realising potential opportunities while managing adverse effects.

**Risk management process**

The risk management process is the systematic application of management policies and procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk.

**Risk register**

A risk register records the outcomes of risk identification and assessment processes in a systematic way—usually set out in a table—and defines risk scenarios, assessment outcomes, risk control actions and responsibilities.

**ROM pad**

The stockpile of freshly mined ore (“run of mine”) used to feed the mill and process plant.

**Sacred site**

Sacred sites may be parts of the natural landscape such as hills, rocks, trees, springs and offshore reefs that are sacred to Aboriginal or Torres Strait Islander people. They may be places that are significant because they mark a particular act of a creation being. They also include burial grounds and places where particular ceremonies have been held.

**Security**

A financial instrument lodged with the responsible authority which is adequate to cover the estimated cost of closure.

**Sedimentation**

The separation of solids from an aqueous slurry.

**Seepage control system**

May include a compacted foundation or liner (compacted clay or geomembrane), and an under-drainage collection system.

**Slope (tailings)**

Refers to the angle of the tailings containment walls and of the tailings beach.

**Slurry**

A finely divided solid which has settled out from thickeners.

**Social impact**

Detrimental harm to society.

**Social licence to operate**

The recognition and acceptance of a company’s contribution to the community in which it operates, moving beyond basic legal requirements towards developing and maintaining the constructive relationships with stakeholders necessary for businesses to be sustainable. Overall it strives for relationships based on honesty and mutual respect.

**Soil cover**

One or more layers of soil-like materials intended to limit the percolation of rainfall or the ingress of oxygen, or both, into AMD-generating materials.

**Spigot**

A branch off the main tailings delivery pipeline from which tailings are discharged from the containment wall of a tailings storage facility.



**Spillway**

A structure constructed at the perimeter of a tailings storage facility, designed to pass excessive rainfall runoff.

**Stakeholders**

Stakeholders are those people and organisations who may affect, be affected by, or perceive themselves to be affected by a decision, activity or risk.

**Starter wall**

The initial containment wall of a tailings storage facility.

**State of the Environment (SoE) Reporting**

SoE reporting occurs at both the national and state/territory level. SoE Reports provide information about environmental and heritage conditions, trends and pressures for the Australian continent, surrounding seas and Australia's external territories.

**Stewardship**

Stewardship (also known as materials stewardship) is an overarching term that encompasses product, process and resource stewardship. It describes an integrated program of actions aimed at ensuring that all materials, processes, goods and/or services that are produced, consumed and disposed of along the value-chain are done so in a socially and environmentally responsible manner.

**Stope**

Underground mine opening or void.

**Store and release cover**

A vegetated, non-shedding soil cover, aimed at minimising percolation through it by the release of stored seasonal rainfall by evapo-transpiration during the dry season.

**Strategic risk**

Strategic risks are those risks that relate to the interdependencies between an operation's activities and the broader business environment.

**Succession**

The natural process of community change that culminates in the development of the climax community of the area.

**Supernatant water**

The water ponded on a tailings surface following the sedimentation of the deposited tailings slurry.

**Supply Chain**

A supply chain is a chain or progression beginning with raw material and ending with the sale of the finished product or service. It represents the flow of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer.

**Surface water**

All water naturally open to the atmosphere, except oceans and estuaries.

**Sustainable development**

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

**Tailings**

A combination of the fine-grained solid material remaining after the recoverable metals and minerals have been extracted from crushed and ground mined ore, and any process water remaining.

**Tailings beach**

The delta that forms on discharge of a flowable slurry.

**Tailings containment**

Usually constructed initially as an earthen starter embankment, with wall raises constructed using borrow material and/or tailings. Construction may be downstream using borrow material, or centreline or upstream using borrow material or predominantly tailings.

**Tailings management**

Managing tailings over their life-cycle, including their production, transport, placement, and storage, and the closure and rehabilitation of the tailings storage facility.

**Tailings pumping and pipeline system**

Designed to deliver tailings slurry from the mineral processing plant to the tailings storage facility.

**Tailings slurry**

Tailings solids embedded in process water that are produced in the processing plant at a low density, which beach at a flat slope, segregate down the beach, and produce considerable supernatant water.

**Tailings storage facility**

An area used to contain tailings; its prime function is to achieve solids sedimentation, consolidation and desiccation, and to facilitate water recovery or removal without impacting the environment. It refers to the overall facility, and may include one or more tailings storages.

**Temporary closure (care and maintenance)**

Phase following temporary cessation of operations when infrastructure remains intact and the site continues to be managed.

**Tenement**

Some form of legal instrument providing access to land for the purposes of mining.

**Thickened tailings**

Tailings thickened to a high density, which beach at a steeper slope and segregate less than tailings slurry, producing far less supernatant water.

**Thickener**

A device for increasing the density of a slurry.

**Traditional Owners**

Those people who, through membership in a descent group or clan, have responsibility for caring for particular country. Traditional Owners are authorised to speak for country and its heritage. Authorisation to speak for country and heritage may be as a senior traditional owner, an elder, or in more recent times, as a registered Native Title claimant.

**Under-drainage**

The provision of drains beneath a tailings deposit to facilitate their drain-down.

**Upstream method, construction or raising**

Construction of the tailings containment walls in an upstream direction on top of consolidated and desiccated tailings, using waste rock or tailings.

**Value chain**

The processes and practices in the production and use of a material or product that collectively comprise the value of the good.

**VOCs**

Volatile organic compounds are emitted as gases from certain solids or liquids. Some VOCs have short-term and long-term health effects. Organic compounds are widely used as ingredients in household products such as paints, varnishes, wax and many cleaning, disinfecting, cosmetic and hobby products.

**WAD cyanide**

Weak acid dissociable (WAD) cyanide comprises both the free cyanide and the weak or moderately stable complexes such as those of cadmium, copper and zinc, that is readily released from the cyanide-containing complexes (cyanide forms) when the pH is lowered using a weak acid such as acetic acid. The detailed definition of WAD cyanide may differ depending on the analytical method used (refer to Appendix 1).

**Waste rock**

Uneconomic rock extracted from the ground during a mining operation to gain access to the ore.

**Water balance**

The sum of the water inputs; including process water and rainfall runoff, and outputs; including evaporation, return water, water entrained in the tailings and seepage, in a tailings storage facility.

**Water cover**

Layer of surface water (eg. in a tailings storage facility or pit) or groundwater (eg. in a backfilled pit) intended to limit the ingress of oxygen into AMD-generating materials.

