Liability Assessment: A Tool for Mine Closure Planning

By

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Declaration

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ABSTRACT

Mine closure is seen as an inevitable and problematic consequence of the nature of the mining industry. In many countries, the public image of mining is still one of abandoned mine sites and lasting environmental liabilities. In addition to this legacy, lack in planning for mine closure has caused social and economic disruption in mining regions. Responsible planning for closure is a major ongoing issue for the mining industry around the world. It should involve a technical review of the operations, an assessment of mine closure liabilities and a cost benefit analysis from both engineering and environmental perspectives. At present, there is a growing concern over the long-term environmental liabilities of a mine closure process. Despite this concern, no comprehensive research has been carried out on the relevance of a liability assessment for mine closure planning.

The present research has focussed on the development of a liability assessment programme to assist mining companies in planning for mine closure. The research covered the major themes. First, a review of sustainable development in mining, current practices on mine closure and current regulatory systems on mine closure in the US, Canada, Australia, South Africa and Brazil. Secondly, this research concentrated on the development of a new approach to closure planning based on environmental audit procedures. Finally, the developed approach was applied on a case study mine in Brazil to test the methodology.

The research revealed the feasibility of using the liability assessment programme as a tool for mine closure planning. The programme showed to be practical for use within an environmental management system. Establishing robust environmental management systems, supported by liability assessment, will place the industry in a sound position to meet the mine closure challenge. Finally, this research provided a recommended strategy for mine closure in Brazil and suggestions for further research.

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CHAPTER 1 – GENERAL INTRODUCTION

Mine closure is seen as an inevitable and problematic consequence of the nature of the mining industry. The public image of mining is still one of abandoned mine sites and lasting environmental liabilities. In addition to this legacy, mine closure has caused social and economic disruption in mining regions (see for example Neil *et al.*, 1992; Warhurst *et al.*, 1999). This is true throughout the world. Responsible planning for mine closure and rehabilitation of mine sites are major ongoing issues for the mining industry around the world. Some countries including the United States (US), Canada, Australia and, recently, South Africa have developed regulatory systems and guidelines which now require mining companies to deal with the challenge of controlling environmental and legal liabilities associated with closure (see for example BLM, 1994; Champigny and van Heerden, 1995; Doran and McIntosh, 1995; Greeff, 1995; Morgan, 1995; Boraussa, 1996; Cowan, 1996; Jones, 1996; Overholt and Downs, 1996; MCA, 1997; ANZMEC, 1999; Clark, 1999; Danielson and Nixon, 1999). Brazil is in the process of introducing similar regulations.

There is no controversy about the necessity and importance of planning for closure. Proper planning for closure should come during the pre-feasibility study, the design and permitting phase and be upgraded during the operational life of a mine project. The lack of an up-to-date mine closure plan results in severe environmental, socio-economic and cultural consequences (see for example Keyes, 1992; Wolfe, 1992; CDPHE, 1998). Therefore, closure should be integral to the whole of a mine's life plan.

Current practice is to require two types of closure plan during the life of a mining project – a conceptual closure plan (project life) and the final closure plan (at the end of operational phase). Conceptual closure plan, required during the licensing process, should ensure that closure is technically, economically and socially feasible without incurring long-term liabilities. The dynamic nature of mining, however, requires regular and critical reviews to reflect the changing circumstances that may arise from, for example, new policies. Similarly, closure plans will also need to be upgraded or modified because of operational changes, new regulation or new technology and should remain sufficiently flexible to cope with unexpected events. The final closure plan therefore, comprises a number of subsidiary plans, which can be modified as the plan evolves. These typically include a rehabilitation plan, a decommissioning plan and a maintenance and monitoring plan.

The aspects to be covered by a closure plan are generally dictated by regulatory agencies (see for example, BLM, 1994; Doran and McIntosh, 1995; Ontario, 1995; Daigneault and Rosenstein, 1996; Jones, 1996; Overholt and Downs, 1996; Manitoba, 2001a; Manitoba, 2001b). In general, the elements of a closure plan are divided into four categories. They include an introductory section, subsidiary closure plans, an estimate of costs and technical appendices. An introductory section consists of an executive summary; a background to closure, including the history of the company and the mining operation, objectives of closure, closure criteria and after-use of the site; a description of the mine components and a description of the environmental and social resources of the area around the mine. Subsidiary plans mainly consist of methods to decommission and rehabilitate each mine component; measures proposed to minimise adverse effects; details of active and passive care programmes; details of any expected long-term management and maintenance, as well as proposed arrangements to undertake this. An estimate of closure expenditure should address costs based on expected activities required by the plan, a schedule of quantities and standard rates. Technical appendices provide details of any specialist investigations, techniques, methods or innovative research undertaken or proposed (Ricks, 1997).

Most Latin American mining countries, particularly Brazil, lack legislation and regulatory system to address mine closure issues. In Brazil, environmental impact assessment (EIA) is the principal tool of environmental management. EIA has functioned as the permitting document and a plan for rehabilitation of degraded areas (PRAD is the Portuguese acronym) must be included in an EIA.

The first objective of this research was to evaluate the Brazilian legislation regarding mining to assess whether PRADs can provide a basic engineering concept for a comprehensive mine closure programme.

Many mines in Brazil are today in an early stage of closure. Despite the absence of closure regulations, many mining companies are still attempting to adopt best practice and are facing the challenge of closing a mine properly instead of simply complying with current legislation or abandoning the mine site. The reasons why planning for closure is becoming more widespread include, *inter alia,* the increasing emphasis on environmental conditions attached to the provision of credit for mining projects; minimising tensions and conflicts with local communities; reducing the risk of future more stringent regulations; improving a company's profile and track record through "greener" operations and corporate policy. The main challenge for mine operators has been how to develop a technically, economically and socially feasible closure plan without incurring long-term liabilities.

This research has focussed on the situation in Brazil, because the absence of directives for mine closure has created many constraints for both operators, in coping with closure, and regulators, as protectors of the public interest. This lack of a regulatory framework for addressing closure matters can also lead to delays in developing projects and investments in the mining industry. There is also an absence of professionals capable of dealing with the wide spectrum of mine closure challenges, which, in the final stages of operations, involve costly time-consuming tailor-made closure solutions on a case-by-case basis. Mine closure plans are prepared in accordance with applicable laws, guidelines and closure criteria established by regulatory authorities. Therefore, legislation and clear guidelines in closure matters are paramount.

Thus, the second objective of this study has been to outline possible key elements of a strategic framework for mine closure that could be adopted in Brazil.

Closure plans are often prepared by external consultants, particularly where there is a requirement for an independent report, but they are increasingly being developed by in-house environmental personnel (see for example, Dahlstrand, 1995; Smith and Hillis, 1996; Ricks, 1997; Hordley, 1998; Milson and Purtill, 1998). However, a review of literature shows that both consultants and in-house environmental personnel have encountered difficulties in planning for closure (see for example, Scales, 1991; McArthur, 1994; Dahlstrand, 1995; White, 1996; Barnes *et al.*, 1999). Most of these difficulties are related to a lack of assessment of mine closure liabilities, lack of qualified personnel, lack of environmental data and poor knowledge of environmental regulations and lack of community participation. As a result, mine closures have incurred unexpected long-term liabilities and closure costs that exceed earlier estimates. To overcome these implications, planning for closure should involve a technical review of the operations, an assessment of mine closure liabilities and a cost benefit analysis from both engineering and environmental perspectives.

At present, there is a growing concern over the long-term environmental liabilities of a mine closure process. Despite this concern, no comprehensive research has been carried out on the relevance of liability assessment for mine closure planning. Liability assessment has been used for property evaluation before financial transaction, to establish innocent acquisition during purchase, takeover and merger (see for example, Holliday, 1993; Martella, 1993; Petts and Eduljee, 1994; Bosco, Hickey et al., 1996; Withers and Dubyk, 1996). Regarding mine closure, the management of environmental liability during mining closure and post-utilization of the mine site has also been addressed at property transfer (Anderson, 1995).

Assessment of mine closure liabilities should be seen as an important and necessary activity for closure planning. Indeed, assessment of mine closure liability is much like environmental audit. The similarity lies in the fact that liability assessment for mine closure purposes should focus on controlling environmental impact which is typically the most costly component of meeting closure objectives. Furthermore, by definition, environmental audit "involves the collection, examination and evaluation of evidence to form verifiable conclusions based on evidence collected" (EPA, 1996; ISO 14010, 1996).

Background knowledge as a mining engineer about liability assessment methodology applied to assess mine closure liability indicates that it is comparable to an environmental audit procedure. The main difference is that the scope should be broader to include all mine closure objectives. In this way, liability assessment for mine closure purpose must consider future changes which may occur at a mine site and provide rehabilitation measures to address long-term concerns. Typically, closure objectives should include the protection of public health and safety, minimising environmental impact and provisions for the post-mining use of the land. Liability assessment for this purpose would involve a description of mine site conditions, operations and the environmental management system in place; identification of the main environmental and socio-economic issues related to mine operations as well as to mine closure; review of compliance records and reports;

interviews with regulatory personnel, mine managers and employees as well as with representative members of the communities involved. So called "front-end" assessment, compilation of existing environmental management and operating files and compliance data, are the approaches adopted to identify current and anticipated long-term closure liabilities and the rehabilitation measures required for planning for closure.

The final objective of this study is expressed as the hypothesis, that it is possible to use a liability assessment programme to provide a framework for mine closure planning in Brazil. The results of the investigations undertaken to address this hypothesis would demonstrate the applicability of liability assessment for mine closure planning purposes and the form it would take to achieve best results.

A review of the literature concerning sustainable development principles within the context of the mining industry, the main issues involved in mine closure plans, the regulations and policies governing mine closure, environmental audit techniques leading to the development of a liability assessment programme formed the first phase of this study. The second stage focussed on the application of this programme in a case study. The outcome was the preparation of an audit report and its submission to the company followed by implementation of the recommended actions by the company. The Águas Claras Mine, owned by MBR provided the case study. The mine, in Brazil, is scheduled to cease its mining operations in September 2001. Therefore, the period of closure planning related well to the period of this study. The final stage of the study involved the development of general conclusions from and recommendations for future research in mining closure matters.

This thesis comprises seven additional chapters. Chapter 2 focuses on the issues concerning the mining industry, the environment and sustainable development. As such, it provides a view of the issues involved in the concept of sustainable development in the context of the mining industry. The chapter gives a historical review of environmental issues concerning mining activities since the early discussion of mining by the scholar Agricola in the sixteen century. The concept of sustainable development is examined taking particular account of the role of international organisations and local governments as well as the commitments of mining associations in establishing policies to achieve sustainability. Some actions of the mining companies promoting sustainable development are examined especially adoption of the so-called "triple bottom line" principle integrating economic, environmental and socio-cultural considerations into business strategies. Minimising the impact of mine closure through appropriate plans is discussed with respect to its crucial role in ensuring sustainable development by minimising the environmental, socio-economic and cultural burdens on future generations.

Chapter 3 evaluates how mine closure can be best designed by the mining industry in order to contribute to long-term sustainable development of a given region. The key impacts to be addressed in mine closure planning are reviewed. Following, a set of objectives and principles grouped under six key areas (stakeholder involvement, planning, closure cost and financial provision, financial guarantee, closure criteria and relinquishment) of a comprehensive mine closure programme are discussed.

Chapter 4 presents an overview of the Brazilian legislation pertaining to mining, the mining code, environmental laws and regulations applied to mining. Following, results of an analysis of some Plans for Rehabilitation of Degraded Areas (PRAD) are presented in order to assess the quality and importance of these plans for a comprehensive mine closure programme. This is followed by an summary of mine closure policy, legislation and regulations in a number of selected countries and an assessment of the evolving nature of government responsibilities with regard to mine closure. This overview serves as a base to discuss the main problems facing mine closure in Brazil and to propose the increasing range of issues that must be accounted for in the Brazilian policy, legislation and regulations on achieving comprehensive mine closure and sustainable development. To conclude a framework for mine closure programmes in Brazil is proposed.

Chapter 5 contains an analysis of the environmental auditing programmes that appear most appropriate to mine closure. These are mainly, "Phase 1 Liability Assessments", Regulatory Compliance Audits and Environmental Management System Audits. The Chapter focuses on the design and execution of an environmental audit programme as well as on implementing the audit recommendations and outcomes of an environmental audit. In addition, a liability assessment programme, developed to assist mining companies in planning for closure and based on the results of this review, is also presented. The objectives of this programme are to identify the current and potential long-term liabilities of a mine project and to estimate the measures needed to meet mine closure objectives. Audit guidelines have been prepared based on the rehabilitation and closure measures that appear to be commonly required. These guidelines represent a plan of how the auditor would accomplish the objectives of an audit.

Chapter 6 chapter presents an analysis of the liability assessment approach adopted at Águas Claras Mine by comparing with the theoretical method presented in Chapter 5. It begins with the discussion of the reasons for selecting Águas Claras Mine as a case study following by an analysis of the MBR top management commitment, scope of the liability programme, auditors' team, mine site interviews and audit follow-up issues experienced when conducting the liability assessment are provided. Outcomes of the research conducted at the Águas Claras Mine are also discussed.

The findings from the case study are presented in Chapter 7. This chapter begins with a review of Águas Claras Mine in the context of MBR and the surrounding area. It follows by a description of the liability assessment findings and it concludes with a summary of the main liabilities emerged from the assessment. The results of this case study were submitted to the mining company as a liability assessment report. It can be stated that the company's response to the measures suggested was favourable since MBR conducted a phase 2 liability assessment and a risk assessment as recommended by this study. In addition, by the end of 2001 MBR submitted the final closure plan to the environmental agency for appreciation.

Chapter 8 assesses the importance of planning for mine closure today and the challenge faced by both mine operators and regulatory authorities in coping with closure. A recommended strategy for a mine closure programme applicable to Brazil is presented with emphasis on the role of the mining industry in contributing to this process. Following these recommendations, the conclusions provide a summary of the Águas Claras Mine project, the case study used in this research, as well as the constraints and challenges in adopting the liability assessment programme for mine closure planning. The extent to which the results of this investigation demonstrate the applicability of liability assessment as a tool to assist mining companies, which have operating mines, in planning for closure is discussed. Finally, issues for further investigation are suggested.

CHAPTER 2 – MINING AND SUSTAINABLE DEVELOPMENT

INTRODUCTION

Since the Earth Summit in Rio de Janeiro in 1992, the expression "sustainable development" has been widely used in every possible context. In the context of the mining industry, sustainable development is still controversial. Indeed, sustainable mining appears to be an oxymoron. Mineral deposits are finite in size and non-renewable for unlike biological resources, minerals cannot be replaced. By definition, therefore, mining of a deposit cannot be sustained indefinitely.

On the other hand, from a global perspective mining as an industry has, in itself, been sustainable. It has been continuously sustained since humans found they could recover resources from the ground. At a local scale, however, it is not. For example, there are today no longer any metal mines in Germany. Around Chemnitz and the famed Ertzgeberge (ore mountains), a prolific mining area since when Agricola first published the mining treatise "*De Re Mettalica*" in 1556, there are today only mining museums to remind us of this once prosperous industry and the world's largest rehabilitation project at the Wismut Uranium Mine, mined for the Russian nuclear programme (E&Mj, 1998). Despite depleting mineral resources, the mining industry has promoted, in a general sense, economic development in some, but not all, countries where it takes place.

The issue now, is how mining can promote sustainable development. Historically, mining has promoted perception as an unsustainable industry by defining its environmental, social and economic responsibilities narrowly. Where costs could be externalised, they frequently have been. The legacy and, in many places, current practice is one of abandoned mines, scarred landscapes, ghost towns, air and water pollution and so on. In addition, when mines are closed, apart from the disturbed natural environment, their direct economic value comes to an end with traumatic economic and social implications for those affected.

To promote sustainable development, mining companies must integrate the economic, social and environmental dimensions of their activities (Mikesell, 1994). They must shift their focus from an end-of-pipe environmental response to a more socially accountable and responsive approach. A partnership with the community must also be forged based on a supply-side approach, whereby the productive and cultural potential of the community is recognised and devoted to improving members' living standards and income (Epps and Brett, 2000). Finally, because mines do not last for ever, mining companies should use their financial capacity to stimulate the local government into facilitating non-mining economic development (Khanna, 2000). This will help increase the infrastructure of services, absorbing excess labour and, as a result, reducing the political and social pressure on the mine.

Cragg (1998) defends the adoption of sustainable development principles at the core of mine planning, operation and closure as a means of making mining an industrial activity defensible and credible over the long term. This, therefore, constitutes the way ahead and the most significant challenge for the mining industry today. In addition, as noted by James (2000), for the mining industry to become a sustainable industry, it should manage its business with attention to the "triple bottom line", which means integrating economical, environmental and social growth into its business strategies. By behaving responsibly from the outset through to the closure of a project, the mining industry can build a relationship of trust with the community.

ENVIRONMENTAL CONCERNS IN MINING

Rickard (1947) wrote that the term 'mine' has the same root as 'menace', both of which are derived from the Latin 'threat'. In this way, it can be conjectured that the threat was not only to the life and limb of miners of the time, but also to the environment. The beginning of environmental awareness in western societies is recorded as early as the year 1306 when King Edward I of England introduced a proclamation forbidding the burning of coal in order to reduce atmospheric smoke near London (Jones, 1992). The mining treatise "*De Re Metallica*" published by Georgius Agricola in 1556, as translated by Herbert and Hoover (Agricola, 1950), contains a number of interesting sections dealing with the environmental perceptions of the population of that time *vis-à-vis* the mining industry. Three passages from Agricola's book I, quoted below, indicate that the environmental arguments surrounding the mining industry are much the same today as they were 450 years ago.

The first passage could be considered as the anti-mining argument: "But beside this, the strongest argument of the detractors is that the fields are devastated by mining operations, for which reason formerly Italians were warned by law that no one should dig the earth for metals and so injure their very fertile fields, their vineyards, and their olives groves. Also they argue that the woods and groves are cut down, for there is need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water, which has been used, poisons the brooks and streams, and either destroys the fish or drives them away. Therefore the inhabitants of these regions, on account of the devastation of their fields, wood, groves, brooks and rivers, find great difficulty in procuring the necessaries of life, and by reason of the destruction of the timber they are forced to greater expense in erecting buildings. Thus it is said, it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces"(Agricola, 1550, book I, page 8).

Agricola notes what might be considered the pro-mining case: "If we remove metals from the service of man, all methods of protecting and sustaining health and more carefully preserving the course of life are done away with. If there were no metals, men would pass a horrible and wretched existence in the midst of wild beasts; they would return to the acorns and fruits and berries of the forest. They would feed upon the herbs and roots, which they plucked up with their nails. They would dig out caves in which to lie down at night, and by day they would rove in the woods and plains at random like beasts, and inasmuch as this condition is utterly unworthy of humanity, with its splendid and glorious natural endowment, will anyone be so foolish or obstinate as not to allow that metals are necessary for food and clothing and that they tend to preserve life?" (Agricola, 1956, book I, page 14).

Further, Agricola attempts to balance these two points as can be seen from the following quotation: "Moreover, as the miners dig almost exclusively in mountain otherwise unproductive, and in valleys invested in gloom, they do either slight damage to the fields or none at all. Lastly, where woods and glades are cut down, they may be sown with grain after they have been cleared from the roots of shrubs and trees. These new fields soon produce rich crops, so that they repair the losses which the inhabitants suffer from increased cost of timber. Moreover, with the metals which are melted from the ore, birds without number, edible beasts and fish can be purchased elsewhere and brought to these mountainous regions" (Agricola, 1950, book I, page 14).

Ancient philosophers such as Seneca, Ovid and Pliny discussed the negative aspects of mining (Agricola, 1950). Later, social philosophers such as Henry Cornelius Agrippa, Edmund Spenser, John Milton, John Donne and Boruch Espinoza led the way in portraying mining and industrialisation in a negative light (Marcus, 1997). During the early 20th century, the British novelists Richard Llewellyn in "How Green Was My Valley" (Llewellyn, 1997) and Alexander Cordell in "The Rape of the Fair Country" (Cordell, 1961), illustrated the depressing life of miners and steel workers of the late-Victorian era and also described the negative effects of mining on the beautiful Welsh countryside. They were all helping to sow the early seed that would eventually flower into the birth of the current vigorous and politically active environmental movement in the latter part of the 1960s.

Epps and Brett (2000) highlight three distinct phases of the mining industry in this century. The pre-1950 period is characterised by large international companies, based in the capitals of the colonial powers, exploiting mineral reserves within the dominions of their empires with little regard for the local inhabitants and simply imposing their own view of mineral rights and land ownership. There was neither mutual adjustment with local or traditional landowners nor an adversarial relationship, since local communities had no power to exercise against their all-powerful "conquerors". This period ended following the Second World War when a wave of nationalisation of mining operations commenced, extending to the mid 1980s.

The last two decades of the 20th century have been characterised not only by globalisation, but also by a new sense of environmental awareness and social activism. In the 1980s and 1990s, world political and economic changes forced governments to turn to private capital once again to rejuvenate their mining enterprises. Immediately before these changes, however, the environmental movement, which commenced in the 1960s and

1970s, significantly altered the public view of how mining projects should be evaluated and how governments' policies should be designed. This period highlighted both the low reputation and the environmental performance of an industry facing growing community expectations. The approach became focussed upon the perception that "economic development is to propose and environmental regulation to oppose" and that economic prosperity and environmental protection are supposed to result from a resolution of this conflict. Although initially driven by a strong public environmental consciousness, this conflict has now translated into the search for sustainable development. In its simplest terms, this is about the traditional environmental agenda being broadened to include social issues, bringing the environment, the economy and society together in one category, sustainability. This attitude is forcing an examination of the social dimension of the industry and a more efficient decision-making process that aims at cooperation between all interested parties, ensuring that everyone benefits.

SUSTAINABLE DEVELOPMENT

The availability of natural resources to sustain economic growth has given increasing concern since the industrial revolution in the 18th century. Various countries, mainly European, have sought to solve this by expanding their borders subjugating many peoples in doing so. By the end of 19th century, natural resources had fundamental importance in terms of political affairs and military matters being competed for by imperialist nations. In the 20th century, natural resource issues were evident during the world wars. After the Second World War, reconstruction of the countries destroyed by war demanded enormous amounts of natural resources. The continuous development of science and technology, however, ensured that no supply crises occurred to impede the economic growth of the developed countries.

In 1972, an unofficial group "*The Club of Rome*" reiterated concerns regarding the global scarcity of natural resources (Meadows, 1972). Scientific and technological advances, however, have continued to permit the enlargement of food and raw materials supply. Production diversification, better management of known natural resources and the discovery of new sources, generally with the development of long-distance transport systems have made economic integration and the availability of natural resources feasible.

Nevertheless, the issue of how to reconcile economic development with natural-resource availability for further generations introduces the concept of sustainable development.

Sustainable development is a grand ideal, about which a vast literature has rapidly emerged. The following discussion maps the historic events characterising the evolution of sustainable development. Among the most significant milestones were the first National Environmental Policy Act (NEPA) in the United States in 1969, the Club of Rome in 1972, the World Conservation Strategy of 1980 (IUCM, 1980), the Brundtland Commission in 1987 (Brundtland, 1987) and the Rio Earth Summit and Declaration of 1992.

The Brundtland Commission first officially introduced the concept of sustainable development in 1987 in their report "*The Common Future*" (Brundtland, 1987). It was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This principle became the focal interest of the United Nations Conference on the Environment and Development (UNCED) held in Brazil, June 1992 generally referred to as the Rio Earth Summit. The Brundtland Commission, along with the 1992 Earth Summit, marked a transformation in how national governments, policy makers, consumers and industry alike viewed industrial activity, trade and the processes of consumption and production. Several important agreements on sustainable development came out of the UNCED. These were:

- "The Rio Declaration on Environment and Development", a political declaration signed by 182 Head of States, consisting of 27 principles. The first principle stated "The human being is the centre of concern in sustainable development".
- States have the sovereign right to develop their own national resources without endangering the environment of neighbouring countries.
- "Agenda 21", a programme of agreed strategies for managing environmental and developmental matters. The programmes are divided into Social and Economic Dimensions, Conservation and Management of Resources for Development, strengthening the role of major groups and means of implementation.

According to Carbon (1997), two important lessons can be summarised from these events. First, environmental protection and sustainable development are based upon a system of values. Whilst such values have common elements, they do not apply to every social, cultural and economic situation. It is often helpful, therefore, to formulate values appropriate to a particular situation in order to determine suitable specific actions. Second, sustainable development requires action going beyond the requirements of regulatory control. Partnership between the entrepreneurs, environmental agencies and communities involved is better than confrontation.

Sustainable development is multidimensional. The first dimension emphasises the sustainability of the natural environment, which includes both environmental quality and the stock of natural resources. The natural environment is an asset. As such, it provides life-sustaining and aesthetic "services": soil, air and water, necessary for all life forms, energy and mineral resources, essential to modern society, habitat for plant and animals, scenic vistas and so on. These services relate to physical sustainability. In addition to physical sustainability, however, the natural environment should be preserved for its own sake.

The second dimension emphasises the economic sustainability of human living standards. Although difficult to quantify, a broader measure of human living standards should be adopted such as the Human Development Index of the United Nations Development Programme. This index incorporates gross domestic product, education, life expectancy and other factors related to economic development. Economic sustainability involves substitution of man-made capital for natural resources. According to Eggert (2000), an important issue arising from substitution is the extent to which it is possible to substitute man-made capital for natural resources.

The third dimension emphasises social and cultural sustainability. It is the most difficult to measure and define because it involves what is fair or just, concepts over which even reasonable people may disagree. Eggert (2000) focuses this third dimension upon two major issues, distribution and process. An important concern is that the distribution of the benefits and costs of developing natural resources may not be fair, equitable, or just. Specifically, much of the benefit goes to the shareholders and to governments in the form of tax revenues, while associated costs are borne by the local community in the form of social disruption, environmental damage, or loss of cultural identity. 'Process' refers to how decisions are made and the role that various entities play within this process.

Therefore, a general proposal for making the distribution of benefits and costs more equitable involves process. In this way, consultation with and involvement of all stakeholders in decision-making is defended, as it achieves outcomes which are socially and culturally sustainable.

MINING AND SUSTAINABLE DEVELOPMENT

In 1986, the Brundtland report emphasised the importance of sustainability in every sector of development, particularly the industrial sector. Although the mining industry provides the basis of most industrial activity, the vital links between mining and sustainable development were not presented in this report. The first attempt to articulate what the concept of sustainability means in the context of mining and minerals development came in 1991 with the Berlin Guidelines on Mining and Development (U. N., 1992). Berlin Guidelines established criteria for assuring sustainable mining and defined the concept of "sustainable mining" as an efficient industry that seeks to minimise the adverse environmental impacts of its activities, especially in developing countries. The interdependence of economic development and environment protection, however, came in 1992, a conference on mineral resources development and the environment organised by the United Nations in New York (UNDTCD, 1992). Moreover, in Agenda 21, it was acknowledged that global indicators for mineral resource development must be among the fundamental indicators for sustainable development.

Since the concept of sustainable development came to prominence there has been much debate on whether the mining industry can be a component of sustainable development. In a strict sense, mineral production is the quintessential unsustainable activity. Once the resource is extracted and used, it cannot be renewed. Therefore, not only does mining not contribute to sustainable development, it runs counter to the very principles of sustainability.

Such a perspective, however, contains several misleading preconceptions. The concept of mineral reserves is dynamic; estimates at any time reflect the economic, technological, legal and political conditions of that time. Over time, as these conditions change, so too do reserve estimates. Eggert (1994, 2000) lists mineral exploration and development, technological innovation and recycling as factors by which mineral production has been shown to be more sustainable than at first appears. Through mineral exploration and development, new mineral resources have been replacing the reserves which mining depletes. By definition, mineral reserves are those that are known with a high degree of certainty of being profitably mined under prevailing economic, political and technological conditions. Generally, at or near existing mines, companies discover and develop new reserves that extend (or sustain) the life of these operations. During feasibility studies for a mineral resource discovery, usually a fraction of the resource is delineated as reserve. Given the cost of developing reserves, it does not make economic sense to determine the complete size and quality of a mineral resource before mining begins. On a broader scale, exploration and development activities also sustain mineral production by leading to the discovery and confirmation of reserves at previously known or unknown mineral deposits.

Mineral production can also be sustained via technological advances and better performance by the mining industry. Technological progress allows either technically difficult or uneconomic (known) mineral resources to be converted into reserves (Villas Bôas, 1997). Such advances make feasible the development of resources at greater depths, of lower grade, or of greater metallurgical complexity. Furthermore, advances in exploration technology, associated with high prices over time, suggest that discovery and innovation together have more than compensated for the effects of depletion over the last half century (Lambert, 2001).

In addition, political conditions at both international and national levels have an important effect upon mineral resources and reserves. The oil crisis of 1970s provides the best known example. The resultant high price of barrel of oil led to the search for new reserves and allowed known resources to turn into reserves. More recently, in Brazil, a proposal running in the Congress to permit mining in indigenous land has encountered strong opposition not only from the environmentalists, but also from international mining companies. The reason why certain international mining companies lobby against approval of this project is that the development of known mineral resources in indigenous land can lead to a drop in the price of many mineral commodities. In 1985, for example, the high production of Brazilian tin by informal miners in the Amazonian region reduced abruptly the tin price leading many mines to closure (Warhurst and Jordan, 1992).

Recycling, although not making mine production itself sustainable, sustains the benefits provided by the material which mining supplies. Recycling is an important source of many metals and, recently, also of non-metallic materials such as cement and construction aggregates. As such, recycling can be considered an important element of a sustainable minerals policy (NRC, 1996; NRC, 1997; NRC, 2000).

The concept of sustainable development for mineral resources should overcome the simplistic conception of a non-renewable, finite mineral resource and the view of global scarcity contained in the Club of Rome Report of 1972. The mineral industry cannot be considered non-sustainable, simply, because it is dependent on resources that are non-renewable. Sustainable development, moreover, is not a one-dimensional concept. According to Hancock (1995), this thinking, associated with the prevailing argument that the environment and biodiversity are best served by preserving ever more land under some conservation designation distracts attention from the important issues of sustainable development. These issues are energy inputs, sequential use of land, disposal and recycling of end-products and closing the production-consumption cycle by focussing more upon high value quality production of longer-life products rather than quantity (NRC, 1996; NRC, 1997; NRC, 2000).

Economic sustainability focuses upon maintaining or enhancing the economic well being of human beings. Using mineral reserves to sustain economic well-being is important for those local communities, regions within nations and entire nations for which mineral revenues are a significant share of the total output of goods and services. Tilton (1992) notes that the extent to which mineral production contributes to economic well-being depends upon three factors. First, mineral wealth must be developed; mineral reserves on the ground are a dormant asset. Second, to sustain the benefits of mining after mineral reserves are depleted, an appropriate portion of the profit must be invested in activities that will generate income or well being in the future, such as education, technological research and development and social infrastructure. Third, governments need to control the potential negative macroeconomic consequences of mining booms, sometimes referred as the "resource curse".

The concept of sustainable development is that each generation should maintain the capital value of the resources that it inherits. For mineral resources, this can be done by a combination of exploration, technological advances, recycling and substitution to maintain the value of the stock of economic mineral resources and by substituting mineral reserve capital with man-made capital derived from mineral resource production. Mikesell (1994) envisages this capital being accumulated from annual depletion payments made for each mineral to make good any depletion in value of stocks as recorded in a nation's natural resource accounts.

Sustainable development in the mining industry incorporates the following elements:

- Finding, extracting, producing, adding value, using, re-using, recycling and, when necessary, disposing of mining industry products in the most efficient, competitive and environmentally responsible manner possible, utilising best available practices;
- Respecting the needs and values of all resource users, and considering those needs and values in government decision-making;
- Maintaining or enhancing the quality of life and the environment for present and future generations; and
- Securing the involvement and participation of stakeholders, individuals and communities in decision-making (NRC, 1996; Andrade, 1997; NRC, 1997; Villas Bôas, 1997; Ackermann, 1998; Munchenberg, 1998; Eggert, 2000; NRC, 2000).

The widespread public acceptance of sustainable development has had three major consequences in the mining industry. First, it has led to an expansion in the definition of environmental concerns to include social, cultural, economic and environmental impacts of mining projects on local communities from exploration through to post-closure (Clark and Clark, 1996; Miller, 1997; Munchenberg, 1998). At present, environmental concerns involve effects not only on the physical health of individual and on ecosystems; the focus has shifted to a more comprehensive view of human well-being and the rights of local inhabitants to determine the quality of their lives and those of the next generation. Second, sustainable development demands the consideration of economic development and environmental regulations from the very beginning of a proposed project. Third, it includes valuation at the project level of values based on moral and other subjective community considerations, rather than only traditional economic values (Cordes, 1997).

These three elements are intricately interlocked, suggesting that sustainable development needs to be measured on a broader scale than at the level of an individual mine, factory or household site. The question for the mining industry then becomes one of maximising its contribution to sustainable development at this broader scale. In practical terms, this means maximising the environmental, economic and social returns gained from mineral resource development. The critical issue remains, however, the need to strike a sustainable balance. Simply maximising economic or social returns from resource development will not contribute to sustainable development. Progress under the three headings of environment, economy and society varies, with social concerns not being so well developed (Eggert, 1994; Warhurst, Macfarlane et al., 1999).

International Context of Mining and Sustainable Development

Global mechanisms have encouraged dialogue on matters related to mining and sustainable development. Different organisations have adopted measures for dealing with innovation, technology development, investment, market access and trade barriers, as well as the development of corporate national and international policies. Some examples come from the Asia-Pacific Economic Cooperation (APEC), Mines Ministries of Americas (CAMMA is the Spanish acronym), World Mines Ministries Forum, as well as the United Nations, the World Bank and mining associations.

In 1995, the forum for Asia-Pacific Economic Cooperation (APEC) established an Expert Group on Mineral and Energy Exploration and Development (GEMEED) to discuss mining and energy exploration, as well as development issues in the Asia-Pacific region. Recently, GEMEED has included a specific focus on the sustainable development of mining.

Since 1995, mines ministers and senior officials from countries in the Americas and the Caribbean (CAMMA) have been meeting annually to renew their commitment to the principles of sustainable development and to discuss ways of implementing Agenda 21. The commitments adopted include: work together on the adoption of sustainable development principles by the mining industry (CAMMA, 1997), recognise the value of stakeholders consultation (CAMMA, 1998) and adoption of mine closure plan requirements at the outset of a project as an element to enable mining to contribute to sustainable development while facilitating the existence of clear and stable conditions for achieving economic, environmental and social well-being (CAMMA, 1999; CAMMA, 2000).

The Role of International Organisations

In the last two decades, international organisations (IGOs) have contributed to the evolution and refinement of the concept of sustainable development. According to Otto (2000), IGOs have, in effect, brought the sustainable development concept to centre stage and provided the impetus to governments to consider how the concept applies to their country and how resulting policies can be implemented. IGOs do not develop effective sustainable development regulatory systems, but they do shape public debate on sustainable development issues and influence the actions of not only governments but of all stakeholders. Ostensoon (2000) lists three important ways that IGOs contribute to the application of sustainable development. First, IGOs have supported the formulation of international standards, norms and guidelines. Second, IGOs have assisted the governments of developing countries in preparing and implementing legislation and administrative practices intended to promote sustainable development. Third, IGOs have contributed to the advance and dissemination of scientific and technical knowledge as well as of statistics, basic economic data and innovations in the area of environmental and socio-economic management.

In general, since the beginning of the international environmental debate, the activities of the IGOs reflect the constant balance of material development interests and sustainability objectives. The outcome of this balancing act and the extent to which the objectives are successfully integrated into a holistic philosophy of development vary over time and from one organisation to another, depending mainly on its mandate.

Otto (2000), notes that the support of specialised IGOs for governments in designing and drafting mineral regulatory frameworks has changed over the last decade. Some United Nations (UN) agencies, for example, have been disbanded or have experienced severe budget cuts. The UN Centre for Transnational Corporations (UNCTC) and the UN

Department of Technical Cooperation for Development (UNDTCD) historically provided mining advisory services. UNCTC was dissolved in the early 1990s and UNDTCD has been incorporated into the Conference on Trade and Development (UNCTAD) where its work on matters relating to mining have markedly declined. Other UN agencies such as the Commission on Sustainable Development (UNCSD), Environment Programme (UNEP), Industrial Development Organisation (UNIDO), International Labour Organisation (ILO), Revolving Fund for Natural Resources Exploration (UNRFNRE) lack the mandate (the mining sector is usually accorded a very low priority), budget or legal staff to fill effectively the void left by the dissolution of UNDTCD and refocusing of UNCTC.

Otto (2000) adds, however, that other IGOs have replaced or are working together with the UN regarding mineral regulatory matters. Indeed, such matters have been largely restricted to efforts by the World Bank. World Bank support has been given, directly, through advisory services for countries drafting mining sector laws and, indirectly, by pressuring governments and companies to implement a broad range of "green conditionalities" as part of its lending practice (Goodland and Daly, 1995; World Bank, 1996).

Various aspects of mining and its impact on environmental and human health have been examined in a series of international fora. In 1992, The United Nations created The United Nations Commission on Sustainable Development (CSD) to ensure effective response to the commitments made at the United Nations Conference on Environment and Development and to monitor and report on implementation of the Earth Summit agreements at the local, national, regional and international levels. The CSD is a functional commission of the UN Economic and Social Council (ECOSOC), with 53 members (CSD, 1999).

In 1999, the United Nations Environment Programme (UNEP), together with the United Nations Department of Economic and Social affairs (DESA), sponsored an International Round Table on Mining and the Environment to review draft guidelines for mining and sustainable development, named Berlin II (NRMU, 1999). The Organisation for Economic Co-operation and Development (OECD) provides an important forum for member governments to address common problems, encourages cooperation and promotes integration of economic, social and environmental policies. Through programmes dealing with chemical management, pollution prevention and control and waste management, among others, the OECD has developed recommendations that affect national and international policies relating to the mining industry (OECD, 1998).

The World Health Organisation (WHO) and the International Labour Organisation (ILO) also address social policy matters related to mining. An ILO Convention and Recommendation on Safety and Health in Mines was adopted in 1995 (ILO, 1995). At present, ILO has paid particular attention to the iron and steel industry, adopting more than 100 resolutions since 1946. In 1996, it focussed upon basic metal production and future consideration of the occupational health and safety issues associated with the smelting, refining and finishing of non-ferrous metal products. In 2001, a tripartite group of experts is expected to develop and adopt a Code of Practice on Safety and Health in the Non-ferrous Metals Industries that will provide specific guidelines for use throughout the industry.

Some international networks have focussed upon the sustainable development of mining. The International Council on Metals and the Environment (ICME) is a good example. ICME concern for sustainable development focuses on promoting sustainable development policies and practices by firms engaged in the mining and production of metals, which will ensure the safe production, use, recycling and disposal of metals. The ICME charter does not attempt to describe how companies should implement its stated principles, but does provide a framework that individual companies should observe when involved in mining projects (ICME, 1994).

It is important to note, however, that positions taken by leading coalitions such, as ICME, in most cases, are not binding upon their members. Even if they are, there is no mechanism for monitoring whether a member is in compliance or not. Rarely do such industry-led coalitions, effectively act as police. Nevertheless, such coalitions play an important role in shaping the thinking of companies with regard to sustainable development issues. In addition, they fund dedicated research on key issues and promote discussion fora, which allow information and the successful strategies of company members to become known to others. Publications of industrial group statements also provide guidance to lawmakers, enforcement officers and courts regarding what defines phraseology such as "international best practice" which are regularly incorporated into mining statutes, regulations and agreements (Otto and Cordes, 2000).

The Role of National Governments

The role of national governments is essential to sustainable development. They are responsible for translating into practice the principles to which they have subscribed at the United Nations Conference on Environment and Development (The Earth Summit) as well as other conferences where resolutions on sustainable development have been adopted. National governments are challenged to develop policies, regulatory and fiscal frameworks to encourage innovation, increase productivity, trade and investment in an environmentally sound and socially responsible manner. Such policies should include the adoption of environment standards, guidelines for assessments and procedure rules. To face these challenges, governments should ensure that the resources, especially the technical expertise, necessary for implementation of policy are available (Davy, 1999; Ostensoon, 2000).

Recommendations for governments enhance the sustainability of mining projects and address such aspects as legal frameworks, strategic planning in the allocation of concessions, management revenues, integration of environmental assessment and social assessment, partnership, monitoring and enforcement (Harries, 1998). Basically, the legal framework should ensure that social and environmental concerns are considered in the project planning and approval process. Governments should undertake strategic planning to guide the allocation of concessions, by identifying constraints on development. This prevents exploration companies from investing in areas where social and environmental matters would act as over-riding constraints to development and conflicts between companies and communities. A legal basis must exist for directing a proportion of project revenue to local developments and transparent tracking mechanisms are need where such systems exist. The management of revenues should promote social equity and alleviate poverty (Davy, 1999).

The economic dimension of sustainable development is particularly important for mining and for mineral economies. The fundamental condition for sustained growth in a mineral exporting country is that the contribution of mineral exports to growth must be maintained over time, regardless of the capacity of the country to maintain its mineral production. What is required, however, is not the sustainability of the mineral exports that initially generate economic growth, but rather establishing and maintaining the macro conditions for sustaining growth. The macro-economic conditions required for sustained development in mineral economies include: preventing price distortions arising from inflation and real exchange rate changes that reduce incentives for production and investment in the tradeable sectors; maintaining the overall volume of investment required for growth by channelling the proper portion of mineral rents into productive investment; avoiding large and prolonged fiscal deficits while maintaining government expenditure for essential social services without impairing foreign and domestic investment; maximizing the resource rents available to the domestic economy; and managing external debt in a manner consistent with sustainable growth (Hancock, 1995; Ackermann, 1998; Harries, 1998; Cooney, 2000).

Commitment of Mining Industry Associations

Members of mining associations around the world, as well as other organisations, are involved in many voluntary initiatives that support sustainable development. Historically, such associations tended to take some defensive posture with regard to regulatory or popular moves which were perceived as a threat to the industry or to its profits. Although true to some extent, many of these associations now approach environmental and sustainable development issues in a proactive, rather than reactive manner.

As a stakeholder group, mining associations have become focal points of dialogue between member mining companies, community groups and government. Initiatives in this direction have had a strong technical orientation with appropriate policies, guidelines and codes of best environmental practices clearly stated. In addition, training and technology transfer have becoming freely available so as to guide worldwide mining operations and to further the objectives of winning stakeholder support for industrial development. Such practices have been used by mining industry associations to accelerate the trends towards improved environmental performance and achieve sustainable development on the part of member companies (Miller, 1997; Epps and Brett, 2000; Otto and Cordes, 2000).

In Australia, the Minerals Council of Australia (MCA) has developed the most comprehensive national mining industry code of practice. The council has policies on specific environmental issues, including multiple land use, trade and environment. To date, the Australian Minerals Industry Code of Environmental Management, launched in December 1996, is the only national mining industry code that calls for disclosure of environmental performance and for independent audits. Cooperation between MCA and the national Environmental Protection Agency resulted in the publication of the "Best Practice Environmental Management in Mining" modules. These modules cover environmental management topics and comprise case studies of best practice (e.g. environmental impact assessment, environmental management system, tailings management and so on). Recently, the Council approved a scoping paper for development of a strategy for mine closure providing a framework for development of solutions to actual or potential environmental, social and safety problems with decommissioned mine sites in order to minimise long-term liabilities for member companies (MCA, 1997).

In Canada, the Mining Association of Canada (MAC) released its Environmental Policy in 1989. Endorsement of this policy is a condition of membership of the Association. By 1990, the Canadian Association released the MAC Environmental Policy followed by an Environmental Management Framework in 1996 (MAC, 1996). This details the principles and general guidelines for implementing a full Environmental Management System (EMS) to be adopted by all MAC members whether in Canada or abroad. Consensus on sustainable development principles amongst MAC members was evident by the end of 1998 (Otto and Cordes, 2000).

In Brazil, the Brazilian Institute of Mining (IBRAM) has an environmental policy to which members are encouraged to subscribe voluntarily . As in the case with the Minerals Council of Australia, IBRAM is now engaged, jointly with the National Department of Mineral Production (DNPM) on a taskforce to discuss the problems of mine closure in Brazil and propose regulations that deal with this issue (Miller, 1997).

In the United States, the National Mining Association (NMA) has issued a code of practice under the title "*Our Common Commitment*". It consists of a statement of principles. Adherence to the code is not compulsory for NMA members, but peer pressure is considered to provide significant incentive for its endorsement by individual companies (Miller, 1997).

As with international industrial organisations, mining associations face the difficulty of effectively policing their membership that can be considered a flaw regarding sustainable development issues. Nevertheless, whilst they may lag behind on enforcement, they lead the way in shaping the manner in which the industry regards and approaches sustainable development.

Sustainable Development Actions of Mining Companies

Environment issues and concerns have traditionally been viewed as a constraint to the mining industry (Belsky, 1992; Farrel, 1994). Nonetheless, the commercial benefits of a proactive approach to environmental management are becoming clear. At present, many mining companies are putting considerable effort into minimising the environmental impacts of their operations, before, during and after the development of resources. Increasingly, companies are investigating how they can make an overall positive environmental and social contribution at a local and regional level. In addition, there is a growing perception by mining companies that dealing with sustainable development issues in a manner acceptable to their stakeholders has become a commercial imperative.

Self-regulation is being promoted as an efficient regulatory mechanism in many mining industries and mining associations, but is increasingly becoming incorporated into corporate environmental policy. According to Guerin (2000), the mining industry, by proposing different methods for achieving underlying environmental goals, affords the opportunity to gain exemptions from specific command and control requirements and an opportunity to show leadership when it comes to environmental matters. Self-regulation, via industry codes of practice and associated standards, are developed for many reasons. These include a desire by industry to reclaim the agenda-setting for their particular sphere of operation, often from other stakeholders. Self-regulation accepts existing legislative requirements as only the minimum standard, but largely implies no legal requirement to comply to anything additional. This has created concern among stakeholders. In its activities, however, the industry shows social responsibility. Furthermore, organisations adopting EMS and associated processes are commonly claimed by advocates to be more efficient and competitive, with a built-in marketing advantage in the long term.

A special edition of the United Nations journal *Industry and Environment* (UNEP, 1998), describes a wide variety of voluntary private mining sector initiatives relating to sustainable development. To achieve sustainable development the mining industry is seeking to adopt and promote strong environmental stewardship over its day-to-day operations. Issues surrounding land use, access and tenure are being addressed while maintaining the balance between the rights and interests of all stakeholders.

Shell and BP have recently announced initiatives which are clearly intended to transform them from "oil companies" into "energy companies", with a substantially greater focus on supplying energy from renewable sources. Both BP and Shell have estimated that 50% of electricity could be generated from renewable sources by 2050 and the companies are positioning themselves to benefit from this shift. This change and the ability to increase greatly the contribution of renewable sources to global energy needs, is only possible because these companies have been able to reinvest returns made from the extraction and use of oil, an example of how the use of a finite resource can give access to a renewable one (Munchenberg, 1998).

In 1998, Placer Dome adopted a sustainable development strategy based on three building blocks. The first block is a corporate policy on sustainability. This was followed early in 1999 by the second in which Place Dome gave a report on its own sustainability performance, which established benchmarks for measuring progress in achieving sustainable development. The third block consists of institutional partnerships, in particular with NGOs. Through these initiatives, earnings from mining have been converted into sustainable social returns for local communities. For example, as part of Placer Dome Asia Pacific's operations at Misima in Papua New Guinea, the mine company has worked with the local Misima communities to establish businesses which will continue to provide income for the communities after mine closure (Munchenberg, 1998; Cooney, 2000).

The Impact of Mine Closure on Sustainability and the Sustainability of Mining Projects

Mining projects are of finite life. As such, the flow of direct benefits derived from mining is unsustained. On the other hand, some of the costs can extend beyond the life of the mine. Long-term mining costs include environmental (e.g., acid mine drainage), socio-economic and cultural impacts. Indirect benefits, such as induced growth effects from infrastructure investments, may also continue after mine closure, but these are less obvious and are normally thought to be swamped by the long-term costs. 'The burden imposed on future generations who must cope with the cost of closed mines' seems, directly in conflict with the notion of sustainable development (Ackermann, 1998). The question today, is to assess whether a mining project has the potential given any necessary intervention by the state, at least, to maintain or improve the welfare of future generations. By doing this, mine closure acts as a crucial step in achieving the sustainable development, by minimising environmental, socio-economic and cultural burdens on future generations.

Environmental impacts should be minimised by effective environmental management and actions from the beginning of a mining project through closure and the post-closure phase. The prospect of mine closure, however, often poses an alarming challenge for mining communities. To protect against a closure scenario that has the potential to severely damage, or even destroy, a fragile economy and a community's social structure, it is important that any company policies fully accommodate the socio-economic and cultural impacts which can result from mine closure (Clark and Clark, 1996). These include accepting full corporate responsibility for ensuring that the proper mitigating measures will be implemented by appropriate and properly supported entities irrespective of the timing or reason for mine closure. Therefore, it is imperative that these policies include the community as an active partner in all phases of a mining project. With good planning and an empowered community, closure should not be feared, but anticipated by all stakeholders as the final stage of community programmes that have been planned from the commencement to culminate in the closure stage.

CHAPTER 3 – MINE CLOSURE

INTRODUCTION

The terms closure, decommissioning and rehabilitation originated as a formal requirement for nuclear installations, but were soon extended to the uranium mining industry. Subsequently, these have been further expanded to encompass the rest of the mining industry (Campbell and Emery, 1995). Mining operations are finite economic activities, which are usually relatively short-term. For a mining project to contribute positively to a region's development in any lasting way, closure objectives and impacts must be considered from project inception. Mine closure planning should be an integral part of a mining project's life cycle and must provide the methods and means to ensure that:

- Future public health and safety are not compromised;
- Environmental resources are not subject to further physical and chemical deterioration;
- The post-mining use of a site is beneficial and sustainable in the long-term; and
- Any adverse socio-economic impacts are minimised (Waggitt and McQuade, 1994; Ontario, 1995; Sassoon, 1996; Sassoon, 1999; Sassoon, 2000; ANZMEC, 2002; EPA, 2002).

The concepts and standards surrounding mine closure are rapidly evolving in terms of the supposed scope and responsibility of the major interested groups, for example government, industry, impacted communities and other stakeholders such as non-governmental organisations (NGOs), lending institutions and other components of civil society (Khanna, 2000). These issues are today much more demanding and stringent than they were just a few years ago and reflect changing public priorities and environmental imperatives.

Mine closure characterises the permanent cessation of operations by a company at a mine or mineral processing site after completion of the decommissioning and rehabilitation process. Final closure is achieved when the completion criteria, an agreed standard of performance that demonstrates successful closure of a site, are met. Decommissioning is an intense part of the closure process, which begins near, or at, the cessation of mineral production and incorporates removal of unwanted infrastructure and services as well as the construction of specific closure components. Rehabilitation (reclamation) is the return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounding land (Knol, 1999).

In essence, mine closure is largely considered by industry and, until recently by most government, as predominantly an environmental issue (Ontario, 1995; Sassoon, 1996; Sassoon, 1999; Sassoon, 2000). This perception, particularly on the part of many governments is changing rapidly. The successful completion of a closure plan will be dependent not only upon adequate planning, but also the development of an effective and efficient approach to funding the closure. This will enable mine site rehabilitation and other environmental objectives to be realised while complying with government requirements and stakeholders' expectations.

Then, to be comprehensive a mine closure programme should begin during the pre-feasibility phase of a project and continue throughout operation to relinquishment of the lease. It should set clear objectives and guidelines, make financial provision and establishes effective stakeholder engagement leading to closure. A financial provision, an accrual based on a cost estimate of the closure activities, is the base for establishing a guarantee which should be lodged with the responsible authority to cover the estimated cost of closure in case of default by the company (ANZMEC, 2002).

The comprehensive understanding of mine closure and ways to reduce the associated economic, environmental and social impacts is relatively new. The objective of this chapter is to evaluate how mine closure can be best designed by the mining industry in order to contribute to long-term sustainable development of the region. First, the key impacts to be addressed in mine closure planning are reviewed. Second, issues including planning, stakeholder involvement, financial provision, closure criteria and relinquishment are examined and their influence on the development of a comprehensive mine closure are discussed.

KEY IMPACTS TO BE ADDRESSED IN MINE CLOSURE

Today the scope of issues that are being considered in mine closure have expanded beyond the more traditional view of site rehabilitation. According to Intarapravich and Clark (1995) a comprehensive programme for mine closure would address the following six major areas of mining impact:

- Impact on physical resources;
- Impact on biological and ecological resources;
- Impact on alternate use values;
- Impacts on quality of life;
- Impacts on social and cultural values; and
- Impacts on sustainable economic development.

The major impacts on physical resources are those associated with changes in the landscape (open pit and shafts, waste piles, tailings dams, physical infrastructure and deforestation) and with water supply (acid mine drainage, metals, particulates) that require extensive treatment and rehabilitation to mitigate their environmental effects (EPA, 1995a; Marcus, 1997; NMA, 1998). A mining closure programme should eliminate or minimise such impacts based upon on the envisaged post-mining land use according to Robertson, Devenny *et al.* (1998).

Biological and ecological impacts are perhaps the most difficult impacts to deal with a mining venture, at least in the immediate area of the mining operations, since mining activity normally displaces or destroys most biological and ecological resources individual species of flora and fauna, unique habitats, unique ecosystems and linked associations of bio-diverse populations. Mitigation of these impacts is a long-term activity and requires the preservation of species, the recreation of former habitats and the non-introduction of foreign species (EPA, 1995a; Marcus, 1997; NMA, 1998).

The use of the land for mining activities, as well as much of the immediate surrounding area, precludes its use for other economic activities – an impact that is further perpetuated when mining areas are abandoned without appropriate closure. Even with comprehensive mine closure the rehabilitated land is often no longer acceptable for use patterns prior to mining. Therefore, it is essential that a mine closure plan be undertaken with alternative use in mind if its use is to be acceptable and sustainable.

Major impacts on human health, safety and welfare may result from mining operations and persist if comprehensive mine closure is not undertaken (for example acid mining drainage, tailings dams instability, water and air pollution) (Orava and Swider, 1996). Particularly, health problems (silicosis, black lung, radiation exposure and metal poisoning) may persist after closure and need to be addressed (Barbour and Shaw, 2000). Impacts on the quality of life are primarily mitigated by the implementation and enforcement of appropriate health, safety and environmental standards during the life of a mine (ILO, 1995), by employing environmentally sound mine closure practices and by leaving in place a social welfare structure that can mitigate any long-term adverse impacts (Warhurst, Macfarlane *et al.*, 1999).

Impacts on social and cultural values occur often when mining operations take place in remote areas, normally regions without previous development activities and result in changes in the social structure and way of life of indigenous societies (McMahon, 1998; Lahiri-Dutt, 1999; Alberts and Grasmick, 2000; Dunn, 2000). The largest changes often are the transfer from an agrarian to urban lifestyle, changes to religions and beliefs, changes in the value and nature of indigenous lands, change in views and relations with the ecosystem and large inter-generational change in mores and values (Clark and Clark, 1996; Davy, 1999). Central to mitigating or accommodating such impacts is government policy, legislation and regulations that ensure the minimisation of impacts from the start of the project; provide for the development and institutionalisation of community and local support to maintain traditional values; and appropriate rehabilitation practices which either allows a return to previous activities or provides alternative acceptable lifestyles (Warhurst, 1999).

In the case of mine closure and post mine development, the issues of infrastructure maintenance and development, the provision of social services (in particular social safety nets for the transition period of mine closure and post-mine development) and alternative employment, shift from being the responsibility of industry to the responsibility of the national and subordinate levels of government policies (Warhurst, 1999).

The mining project phases, the main mining actions plans and environmental management as well as closure activities commonly associated with each phase of a mining project life cycle are summarised in Table 1.

Table 1 – Mining Project Phases, Planning, Environmental Management and Closure Actions

Phases of a Mining Project	Mine Planning Action	Environmental Management and Closure Actions
Exploration	Exploration road construction Rock core drilling Geochemical analysis Geostatistical analysis Orebody evaluation	Environmental assessment Rehabilitation plan Exploration permit application
Pre-feasibility study	Initial mine and minerals process planning Facilities sitting Scheduling Economic analysis Initial technology selection	Environmental baseline study Environmental assessment "Fatal flaw" analysis Initiation of permitting process
Feasibility study	Plan of operations Technology selection Concept of final designs Costing and cost benefit analysis Investment brokerage	Comprehensive EIA and review Mitigation planning Conceptual design for closure Reclamation and closure costing Closure fund design
Development	Ore extraction Site clearing and grubbing Earth moving and surface water management Mine dewatering Utilities installation Building and infrastructure construction	Installation of pollution control facilities General environmental management Construction phase reclamation and closure
Production	Ore extraction Size reduction Minerals processing Smelting and refining Maintenance and upgrade	General environmental management Performance assessment/audit Monitoring Concurrent reclamation Final closure design Partial closure Partial bond release
Closure	Facilities decommissioning Dismantling Decontamination Burial Removal Asset recovery Recycling	Implementation of closure plan Site cleanup Final reclamation Final impact assessment Post-closure planning
Post-closure		Treatment Maintenance Monitoring Final bond release

CLOSURE PLANNING CONSIDERATIONS

Planning for closure involves integrating the closure design for the entire mine area, identifying the timing of the planning process, considering issues which relate to stakeholder involvement and consultation, financial provision and guarantee, completion criteria and relinquishment in order to implement a comprehensive mine closure programme (ANZMEC, 2002).

Integration of other aspects of sustainable development, i.e. economic and societal interests, has not taken place to the same extent as the considerations for environmental issues (Clark and Clark, 1996; Carbon, 1997; Ricks, 1997; Munchenberg, 1998; Clark, Naito *et al.*, 2000; Otto and Cordes, 2000; Sassoon, 2000). It can be argued that the considerations related to environmental issues are still at a fairly rudimentary level and it is therefore clear that much is still to be learned about the successful closure of mines and integrating the economic and social aspects (Ricks, 1997).

In discussing the approach to mine closure and rehabilitation, Knol (1999) and Sassoon (2000) identified three main stages. There are no clear boundaries between these stages and they are often difficult to distinguish. The length of time for each stage can also not be generally defined as it is a site-specific issue, e.g. the active care stage may continue for a number of years or decades. These three stages are:

1. The Planning Stage – rehabilitation plan should be established and integrated into the mine and environmental management plans or system at the earliest possible opportunity and regularly updated during the operating life of the project.
2. The Active Care Stage – the active care programme immediately follows the cessation of activity in a specific area, i.e., the closure of a waste rock dump, or the total cessation of mining.
3. The Passive Care Programme – the passive care programme is a period of sampling and monitoring designed to demonstrate that the active care programme has been successful and the 'walk-away' state has been achieved.

It must be noted that moving from the active care stage to the passive care stage requires that there is not ongoing mechanical water treatment on the site, e.g. a lime treatment plant for acid drainage. Similarly, moving from the active care stage to walk-away may not be accomplished at all at mine sites where passive treatment, water monitoring and ongoing maintenance are required (Knol, 1999; Sassoon, 2000).

The timing of planning for closure is determined by a number of different factors and can influence the closure process itself. Design of a closure plan should start during the pre-feasibility study. As new projects move forward to the development stage, initial reclamation and closure plans as well as estimates are typically adjusted to respond to regulatory requirements for mining permits and bonds. Following mine development, the body of experience grows as well as the amount of baseline information for planning and estimation (ANZMEC, 2002; EPA, 2002). On-going reviews of the closure objectives and design are necessary to allow for changes in local physical or socio-economic conditions. If planning is delayed, it may affect which mine closure objectives can be met. The lack of an up-to-date mine closure plan can result in severe environmental and economic consequences (Mudder and Harvey, 1998; Barnes, Hawthorne *et al.*, 1999).

The next sections are structured around a set of objectives and principles grouped under six key areas (stakeholder involvement, planning, closure cost and financial provision, financial guarantee, closure criteria and relinquishment) of a comprehensive mine closure programme.

STAKEHOLDER INVOLVEMENT

It is generally agreed that, in principle, public involvement in mining-related decision-making and management processes is an important factor in enhancing the legitimacy of the industry, in developing public trust in the ability and desire of mining companies to conduct their business in an environmentally responsible manner, and in improving the quality of the decisions being made regarding environmental management (EPA, 1995d; Anderson, 1998; Hannan, 1998; McMahon, 1998; McMahon and Strongman, 1999; Alberts and Grasmick, 2000).

In today's mining industry policy, community consultation has become a very important part of mining operations. This results from public concern and governments' encouragement and, in some cases, requirement for mining companies to discuss their plans and the environmental results of their activities. Whilst far from universal, the consultation process is moving towards a "cradle to grave" (or exploration to closure) approach (WMI, 1994). More effective approaches to environmental management can be developed, and the public trust in mining enhanced, when the community and other stakeholders are fully informed and participate in the closure process (Anderson, 1998; McMahon, 1998; Lahiri-Dutt, 1999; Alberts and Grasmick, 2000).

In a comprehensive mine closure programme the process of stakeholder involvement includes stakeholder identification, effective consultation and targeted communication strategy. Identifying key stakeholders and interested parties and developing a good relationship with them, is fundamental to a successful closure process. The main stakeholders in the mining industry are the mining firm, the government, the creditors and insurers and the local community. To ensure that all mining phases evolve in a manner that is of benefit to all, it is necessary to take into account all stakeholders in the planning process so that views, interests and constraints encountered by each of them can be considered through a process of consultation and involvement (Ostensoon, 2000).

The process of consultation should begin early in the mine life, preferably during the planning phase, and continue into the closure and relinquishment phase (Epps and Brett, 2000). Consultation should not be on a selective basis, but should involve all parties with a stake in the project and the post-mining land use. Other parties, such as conservation organisations and other non-government organisations, may have an interest in the project and should be included in the consultation process. To be effective, communication must involve listening and feedback, as well as informing. Consultation is as a listening process, especially of people's needs, their fears and their feelings about threats and opportunities. It is about perceptions and reality (Kelly, 1995). It is about just negotiation and satisfactory results for all stakeholders. It is about social, economic and environmental issues of people's lives. Above all, it is about preservation of confidence and a sense of well-being for all stakeholders (EPA, 1995d).

A targeted communication strategy should reflect the needs of the stakeholder groups and interested parties. Closure information distributed to stakeholders should be provided in a timely and coordinated manner, and when a response is requested, adequate time should be provided (WMI, 1994). This is particularly important when infrastructure is being retained for community use, where post-mining land use involves community input, or where the post-mining land use is different from the pre-existing land use (Alberts and Grasmick, 2000). Effective community relations demands that the corporation, its personnel and sub-contractors, have the capacity and desire to bridge the cultural and capacity gaps that often separate them from local communities (Dunn, 2000).

PLANNING FOR CLOSURE

Ontario Guidelines define the preparation of a closure plan before the development of a mine as "designing for closure" (Doran and McIntosh, 1995). The concept of design for mine closure, from the industry's point of view, should amalgamate two separate objectives. First, closed mine components must meet the defined completion criteria. Second, the process of closure should occur in an orderly, cost-effective and timely manner. Therefore, it is necessary to ensure that rehabilitation and closure measures are effective over the long-term (ANZMEC, 2002). Based upon these objectives, a long-term view is necessary to identify processes or forces, which will come to act upon those mine components remaining after closure. The design and implementation of a closure plan must minimise or eliminate long-term risk of failure of components. Where such problems are inevitable, the plan should identify and provide for the necessary long-term maintenance. After closure, wherever practicable, there should be no ongoing intervention or operating activities other than periodic inspections and minimal maintenance.

Design for a mine closure should address the following issues (Warhurst, 1999):

- What are the kinds of environmental and social problems that may continue or arise at the end of the life of the mine?
- How can these impacts be mitigated or avoided?
- When should these problems be addressed in order to be most effective from an environmental, social and economic perspective?
- Who should be involved in the process?

Mine closure should not be an "end of a mining project's life", but should be integral to the "whole life of the project" if it is to be successful (ANZMEC, 2002). The design of a closure plan must begin before mining commences and continue as an integral part of the mine planning process throughout the life of a mine (Warhurst, 1999; ANZMEC, 2002). Early consideration of closure issues, such as final landform stability and beneficial post-mining uses, reduces the cost of rehabilitation and closure effort long after effective mine operations cease (Poling, 1998; Tuttle and Sisson, 1998).

It is commonly expressed that planning for mine closure should start even before mining commences, see for example, Champigny and van Heerden (1995), Leiner, Hammerschmid *et al.* (1995), Boraussa (1996), Cowan (1996), Overholt and Downs (1996), Sassoon (1996), Clark (1999), Danielson and Nixon (1999), Knol (1999), Lima and Wathern (1999) and Warhurst (1999). In many cases, the decisions taken during the initial phases can affect the options available for eventual closure of the mine. Whilst these options should be evaluated during the environmental impact assessment process, they are not always integrated into the actual mine planning. If this early planning takes place, then subsequent activity for decommissioning and closure should focus upon revisiting and refining the concepts and proposals at regular intervals. Flexibility is the key word. It is rare for major operational changes not to be made during the life of a mine. Thus, it is critical that the decommissioning and closure plan can be reviewed and revised to take account of such changes.

At least two types of closure plan will be required through the life of a mine; a Conceptual Closure Plan (for use during feasibility, development and detailed design) and the main Closure Plan (for use during construction, operation and post-operation). Conceptual closure plans form a statement of the intention to assure environmental mitigation by defining the rehabilitation and decommissioning related tasks necessary during mine operations and after closure that are feasible. Conceptual closure plans required to be submitted at the time of the mine permit process, should be able to demonstrate and ensure that closure is technically, economically and socially feasible without incurring long-term liabilities (Anderson, 1995; Brodie, 1998). The Conceptual Closure Plans should also include preliminary land use objectives and indicative closure costs to ensure that closure concepts are factored into final project design.

The main closure plan comprises a number of subsidiary plans with detailed design drawings and construction specifications. These typically include: a rehabilitation plan, a decommissioning plan and maintenance and monitoring plans (Doran and McIntosh, 1995; Knol, 1999; ANZMEC, 2002; Lima and Curi, 2002). In addition, closure plans should include contingency measures for temporary suspension of operations, not involving decommissioning and closure. In this way, a closure plan is seen as a dynamic document, which will be refined throughout the operational phase of the project.

A key component of the Closure Plan is a commitment to progressive rehabilitation. In conjunction with an active research and trials programme, this may assist in minimising ongoing contamination and reduce final costs by confirming or modifying completion criteria and demonstrating that they can be met. Progressive rehabilitation allows best use of available personnel and equipment and should assist in minimising financial guarantees (Ontario, 1995; EPA, 1995e; Cowan, 1999; Sassoon, 2000).

The decommissioning plan should be developed towards the final stages of an operation. As the exact date for ceasing production is rarely known, it is suggested that the decommissioning plan be developed 2 to 4 years prior to estimated cessation (Farrel, 1993; EPA, 2002). Once established, it should be updated annually. The decommissioning plan should include details of the demolition and removal or burial of all structures not required for other uses; removal, remediation or encapsulation of contaminated materials; and the procedures for making safe and sealing, openings to underground workings (Quilty, Walta *et al.*, 1991; Farrel, 1993; Bradburn and Perkins, 1995; Asher and Bell, 1998; Hordley, 1998; Waggitt, 1998; EPA, 2002).

The last aspect of a Closure Plan is maintenance and performance monitoring programmes, which should be designed to achieve and demonstrate that the completion criteria have been met. A plan for remedial action is need where monitoring demonstrates completion criteria are unlikely to be met. If progressive rehabilitation has been successful, with stabilisation and revegetation meeting completion criteria this last phase of closure may be shortened. Depending upon the criteria to be met, it is, however, unlikely to be less than 5 years in duration (EPA, 1995c; Jarvis, 1998).

Mine Closure Plan Management and Implementation

In theory, closure is the converse of commissioning, requiring similar skills levels, operational experience and motivation. The concept of conducting the operation safely, cost-effectively, on budget and on time remains fundamental to its success. Well-planned closure programmes consist of two distinct sequential phases; planning and implementation. According to Hordley (1998) coordinating these stages will result in a well-designed, systematic, safe and cost-effective mine closure. In the management and implementation of closure plans mining companies should take into account the accountability for plan implementation, the resources needed to assure conformance with the plan and on-going management and monitoring requirements after closure of the operation. The Plan should also include the management of social as well as environmental issues.

Mine closure management should ensure that there is clear accountability and that there are adequate resources for implementation of the closure plan. A dedicated team structure reporting to a project manager, as well as well-established and clear roles and responsibilities are fundamental for the success of a plan (Dahlstrand, 1995; Werniuk, 2001). Furthermore, adequate resources must be provided to assure conformance with the closure plan. Provisioning is designed to ensure that adequate funds are available to meet closure commitments. If estimates are inadequate, funds should be provided from other sources. The on-going management and monitoring requirements after closure should be assessed and adequately provided. A self-sustainable post-mining land use should be the main objective of all closure programmes. However, under some closure scenarios (such as the treatment of acid mine drainage) there may be a need to provide long-term, active monitoring of the closure site (Scales, 1991; Werniuk, 2001). Thus, the post-mining management and monitoring requirements need to be assessed and adequate resources provided. In addition a closure plan should include a schedule of actions, responsibilities, resources, timeframes and guides for measuring progress and implementing any changes needed to the plan.

The accountability for resourcing and implementing the closure plan should be clearly identified. The closure process will be enhanced if there is a dedicated team structure, reporting to a project manager. Roles and responsibilities need to be clearly established.

A mine closure programme should be managed as a self-funding operation, complete with comprehensive business plan, including costs, revenues, profit/loss and cash flows. This plan should also include a schedule of actions, responsibilities, resources and timeframes (Hordley, 1998). The development of a business plan provides the basis for implementing the closure plan; measuring progress and highlighting any changes needed to the closure process.

The implementation of a closure plan is a reflection of the status of mining project operations. Mine closure may be initiated in a number of different scenarios, including: planned closure, sudden closure, temporary closure and maintenance and monitoring (Knol, 1999).

Planned closure involves the preparation of an initial conceptual closure plan from which a final closure plan is eventually developed. Such a final closure plan is based upon the current level of biophysical and socio-economic information, as well as mine planning and development details. As the project advances, the closure plan should be regularly updated and refined to reflect changes in mine development, operational planning and environmental conditions (Knol, 1999).

In the event of sudden or unplanned closure, an accelerated closure process will need to be implemented. This involves the immediate preparation and implementation of a decommissioning plan, based upon the pre-existent conceptual closure plan, taking into account the site's non-operational status. One problem in this scenario is the availability of funds, where inadequate provision has been made or, in the extreme case, is totally lacking (Knol, 1999).

Economic and operational circumstances may result in a temporary pause in mining or milling activity. A temporary shutdown of this nature is normally planned and assumes that the operation will recommence. The care and maintenance process involves the immediate preparation and implementation of a decommissioning plan, taking into account the potential for future operations at the site. Site remediation and works to prevent potential off-site contamination should be implemented as if for a final closure scenario. A temporary closure should always generate a review of the final closure plan, which will have to be implemented if circumstances remain adverse to the reopening of the operation (Knol, 1999).

Monitoring and Maintenance

Monitoring should be designed to demonstrate that completion criteria have been met and that the site is safe, stable and has achieved the land use objectives set during the planning process. Of particular importance is the development of support mechanisms for the maintenance and monitoring phase, when operational support (accounting, maintenance, etc.) is no longer readily available. In addition, the need for maintenance recognises that not all closure strategies will be initially successful. All closure situations are unique, and although past experience and good planning can minimise the risks of failure, some remedial activity will usually be necessary (EPA, 1995c; ANZMEC, 2002).

Risk Assessment

Risk assessment is an important tool in planning for mine closure. It encompasses a broad range of issues and approaches, which includes activities to prevent or mitigate damage or loss. Risk assessment should address: what can go wrong? How probable is it to go wrong? And if it goes wrong, what are the consequences? Two major advantages of applying risk assessment to evaluating mine closure options are the selection of practical and cost-effective remedial options. In planning for mine closure risk assessment can be applied in studies involving metals and the environmental risk in the aquatic environment (Kingery, Allen *et al.*, 1992), risks associated with mine flooding for acid mine drainage control (Mavis and Coon, 1992), ranking hazardous waste sites (Johnson, Cothern *et al.*, 1992) and evaluation of potential risks on human health (Strohm and Markey, 1992).

A risk-based approach to planning for mine closure should reduce both cost and uncertainty. Current trends in closure planning involve technical review and analysis of risk and cost benefit in both engineering and environmental terms (Belsky, 1992; Astill, 1994; Bailey, 1994; Farrel, 1994; Swart, Pulles *et al.*, 1998). The advantages of a risk-based approach to closure planning lie in the quantification of subjective factors and the analysis of uncertainty related to both design performance and cost (Morrey, 1999). The objective of a risk-based approach is to reduce both cost and uncertainty. Risks most often considered in closure planning are those related to design failure and long-term liabilities. Other uncertainties associated with closure are related to technology, design and performance; regulatory standards and limits; regulatory agency acceptance and corporate preferences (Morrey and Van Zil, 1994).

Typical Contents of a Closure Plan

The development of a Closure Plan needs to take into account both the legal requirements and the unique environmental, economic and social properties of the operation. Outlined in Table 2 are the typical contents of a Closure Plan, which will vary depending on individual circumstances.

Table 2 – Typical Contents of a Closure Plan, after ANZMEC (2002)

1 – Introduction & Project Description
    Land tenure
2 – Objectives of Closure
3 – Baseline Environmental Data
4 – Legal & Other Obligations
    Key statutes & regulations
    Responsible Authority
    Regulatory instruments
5 – Stakeholder Involvement
    Stakeholder identification
    Community consultation
6 – Risk Assessment
    Existing legacies
    Future risks
    Cost/benefit analysis
7 – Closure Criteria
8 – Closure Costs
    Financial Provisions
    Financial Guarantees
9 – Closure Action Plan
    Human resources/responsibilities
    Progressive rehabilitation
    Decommissioning
    Remediation
    Geotechnical assessment
    Landform establishment
    Revegetation
    Aesthetics
    Heritage
    Health & safety
    Post-closure maintenance & monitoring
    Survey (remaining structures & areas of contamination)
    Documentation/reporting/records
10 – Tenement Relinquishment

Mine closure planning must integrate a number of concepts on a site wide basis, e.g. social aspects, physical and chemical stability including surface water management, the management of remaining process solutions, the selection and implementation of covers and the post-mine use of the infrastructure. Decisions on closure are based on the post mining land use and regulatory criteria. Comprehensive mine closure planning includes a number of elements:

- A **study of closure options**, often a task commissioned to be carried out by consultants, covering the feasibility of all aspects of possible outcomes, not necessarily leading to the recommendations of a preferred option;
- A **consultative process** involving local communities, regulators and others to determine the preferred long-term use for the mine and all associated land;
- A **statement of closure objectives,** which is the mining company's commitment to the outcomes of the closure and its activities. It may be drawn from the study of options but other factors such as regulatory requirements, community preferences, the precautionary principle and corporate culture may also influence the choice. It is the company's statement, after accommodating all inputs, of what it intends to do.
- An **estimate of closure costs**, that is the cost of achieving the stated objectives produced by the other elements above.
- A **programme of studies and test work** to confirm any assumptions inherent in the statement of closure objectives, to reduce the uncertainties surrounding some of the options for closure, and to investigate new technologies or socio-economic models.

The first pass at this cycle takes place during the environmental impact assessment, but a regular review process for closure ideally leads to revisions or confirmation of closure objectives, costs and research needs.

Closure planning must integrate all aspects of sustainable development, i.e. environmental, economic and social issues must be addressed in integrated closure plans. Such integrated thinking must become standard operating procedures throughout the mine life. A comprehensive approach is at this time a theoretical ideal to strive towards and much work remains to implement it universally.

CLOSURE COSTS

Closure costs should, wherever possible, reflect the real costs of closing a mining operation. They may include decommissioning and demolition; removal of infrastructure; remediation; sealing of underground openings; safety bunds and fences; landform reconstruction; maintenance and monitoring; retrenchment and relocation costs; social disruption costs; and administration and management. In addition, maintaining adequate financial guarantees is another item of cost for industry since most guarantees imply freezing a considerable amount of cash in some bond instrument.

Due to the increased stringency in standards for environmental protection on and around mines, closure costs have a tendency to raise not only operating costs during production, but also capital costs at closure. The most expensive closure components relate to physical rehabilitation of mine disturbance and the elimination of long-term maintenance requirements and liabilities beyond closure (Morrey and Van Zil, 1994; Morrey, Van Zil et al., 1995; Morrey, 1999). On the other hand, closure costs may be reduced significantly if concurrent rehabilitation and partial closure of mine components are conducted during the operational life of the mine.

Closure costs are divided in two parts: employee costs such as special retrenchment pay and additional costs such as retirement funds or pensions, and environmental costs including rehabilitation and environmental liabilities (MMSD, 2001). Closure costs are mine-specific and based upon an actual closure design using site-specific requirements. They can vary greatly considering the grade of site disturbance, location of the mine (remote or populated area), ore type, method of mining (e.g., underground or open pit), permit requirements and so on. Following, some closure costs available in the literature are presented to illustrate such a variation. These examples include mines that had a closure plan implemented and mines that were closed or are in closure process by the government because of company's bankruptcy.

Equity Silver Mine in British Columbia ceased operations in 1994. Cost to operate ARD collection and treatment system was estimated at $1,1 million per annum and a financial guarantee established by provincial government was $25 million to pay for long-term treatment. According to Aziz and Ferguson (2002) total environmental expenditures since the discovery of ARD exceeds $20 million. At Sullivan Mine in British Columbia, closed in 2001, anticipated closure costs amounted $70 million. Long-term post-closure operating cost due to ARD is estimated at $1.28 million annually. Bonding to support these costs over 100-year period is estimated between $10 and $20 million (Werniuk, 2001). At Polaris Mine (an underground zinc-lead mine on Little Cornwallis Island), scheduled to close in 2002, closure cost is estimated at tens of millions, a significant amount compared with the $250 million capital cost (Werniuk, 2001). At Elliot Lake Mines in Ontario, closed in 1996, total closure costs in 10 years of closure work amounted C$100 million dollars (Payne, 2000). At Island Copper Mine in British Columbia, closed in 1995, Welchman and Aspinall (2000) reported an amount of 2.76 million of environmental performance bond required. According to Welschman and Aspinall (2000) the results of a concurrent rehabilitation plan and efficacy of the mine closure programme adopted were reflected in such a value of environmental performance bond compared to bonds up to $28 million imposed on other similar operations. At Ridgeway Gold Mine in South Carolina (US), closed in 1999 the cost estimated to perform the rehabilitation work was $15.5 million (Salisbury, 2000). The cost estimated for closing Águas Claras Mine in Brazil to the closure plan is at $14 million.

At Wismut Uranium project in the former German Democratic Republic, closure costs were estimated in $9 billion to be expended in 10 to 15 years starting in 1998 (E&Mj, 1998). Summitville gold mine, opened in 1870's and closed in 1992 the company declared bankruptcy. Environment Protection Agency, Colorado Department of Public Health and the Environment initiated in 1992 the remedial activities under the authority of superfund. Mining company closure cost was estimated as $28 million, subsequently, a contractor estimate was $40 million and a Federal and State Government estimate were $100 million. Today costs exceed $200 million (Robinson, 2002). At Kam Kotia Mine (former copper/zinc mine in Ontario), declared bankruptcy in 1988 closure costs was estimated by provincial government at C$40 million (Werniuk, 2001). At Hope Brook Mine (an open pit and underground gold mine on the Island of Newfoundland), declared bankruptcy in 1999, closure costs was estimated at C$13 million (Werniuk, 2001).

Wismut mines and Elliot Lake mines were former uranium mines. One reason, not considering site-specific conditions, for the smaller closure cost at Elliot Lake (C$100 million) compared to Wismut mines ($9 billion) is that the closure and implementation planning at Elliot Lake had commenced several years before the reality of the deteriorating business climate for uranium become evident. On the other hand, at Wismut mines, closure programme was only initiated by the German government after the Germany unification.

There have been few attempts to assess world mine site liabilities. The numbers differ widely, depending upon assumptions and definitions. However, some indication of magnitude of potential costs is provided with the purpose of showing the importance of planning and implementing mine closure to avoid environmental liabilities. The US Bureau of Mines classified sites by whether they presented 'environmental hazards'; estimated 28,000 sites on federal lands and estimated the clean up cost at US$ 4 to 35.3 billion. The US Forest Service, on the other hand estimated 25,000 abandoned mines on its own land based on the classification "existing and potential environmental degradation." It estimated clean up costs at $ 4.7 billion. The Mineral Policy Centre estimated that there are 557,000 abandoned mines sites in the US and that it will cost $33 to $72 billion to clean them up (MPC, 1993). In Canada, the Mining Environmental Neutral Drainage (MEND) estimates acid mine drainage clean up liabilities at C$3 to C$5 billion (Weatherell and Feasby, 1997). In Australia, according to Harries (1997) such liability is estimated at US$0.9 billion.

Closure costs cash flow

Project evaluations are based upon Net Present Value (NPV). Any costs late in the life of a project (typically after 20 years) will not impact the present value and therefore the investment decision. The mining company could therefore commit to very high closure costs without it impacting the investment decision. However, the cash flow required to implement the closure plan may be so high that it could impact the viability of the company at that time. An example of this is at Polaris Mine where closure cost is significant compared to capital cost amount (Werniuk, 2001).

Figure 1 illustrates three hypothetical scenarios of cash flow considering mine closure cost for a mining project. If the company operates in a regime in which there are no closure responsibilities, the cash flow scenario will follow the line CF1. If the company has a closure responsibility but there has been no closure planning, the company may need to incur costs at the time of closure, which will affect the cash flow at a time when it is substantially reduced. The cash flow scenario will then follow CF2. An integration of environmental costs and planning for closure from the outset will spread these costs through the life of the project, thus, reducing the burden at closure. Concurrent rehabilitation allows closure measures to be integrated into daily operations. In this way, successful rehabilitation techniques are easily incorporated into the final closure plan and allow the discovery of "hidden defects" before ultimate closure. Adverse environmental effects are minimised. Additionally, the use of concurrent rehabilitation means that, as mine components become available for rehabilitation, they can be remediated with the advantage of reducing terminal closure liability. CF3 represents this cash flow scenario (Parrish, 1991; Warhurst and Noronha, 1999).

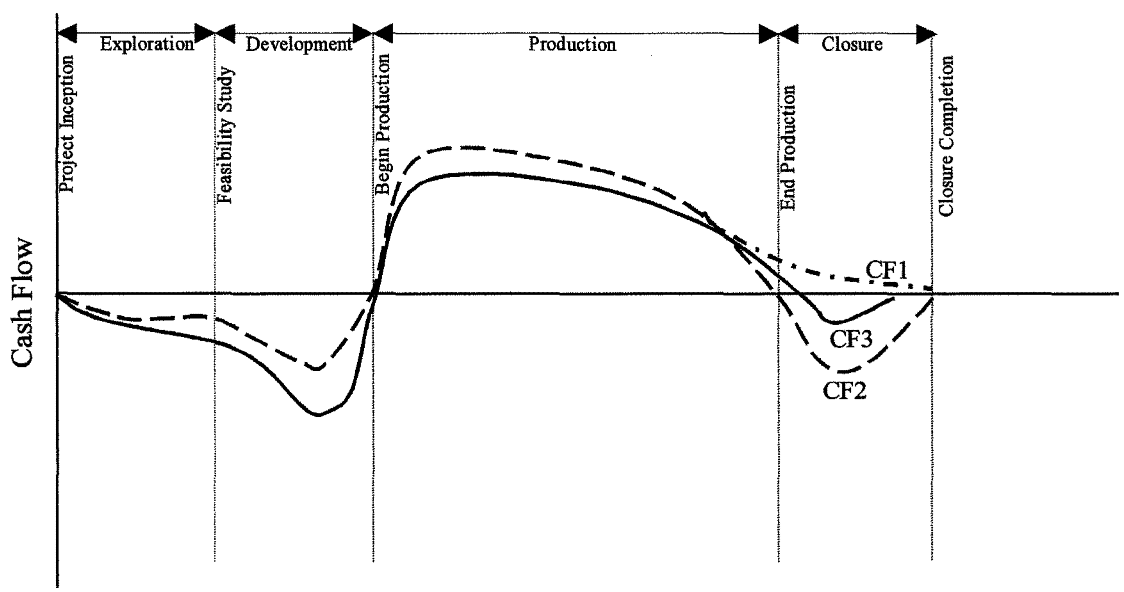

Figure 1 – Cash Flow Scenarios for a Mining Project, After Parrish (1991 and Warhurst and Noronha (1999).

Figure 2, from Brodie *et al.* (1992), illustrates the planned closure cost requirements through the development, operation, closure and post-closure periods of the life cycle of a mine project or a mine component. The closure cost, at the start of the operation stage, is equal to the amount G. This corresponds to the environmental liability from the development stage of the mine, which is made up of overburden removal to expose the mineralised body, construction of waste dumps, tailings and infrastructure, opening access and other operations needed to start mine production. If there is no concurrent rehabilitation through the operation stage of the mine, closure costs (line GI) rise to value I. When concurrent rehabilitation is effective during the operation stage, closure costs (line GH) total H. During the closure period, concurrent rehabilitation reduces the closure liability and closure costs decrease to value J, see the example of Island Cooper Mine (Welchman and Aspinall, 2000). In the post-closure phase, there are two potential scenarios. The first scenario occurs when maintenance and monitoring is required for a short period to demonstrate that closure objectives have been met, line JE. The other scenario, is characterised by a requirement for intermittent or ongoing activity, line JK. Treatment of acid mine drainage is a typical example of this situation (Scales, 1991; Werniuk, 2001).

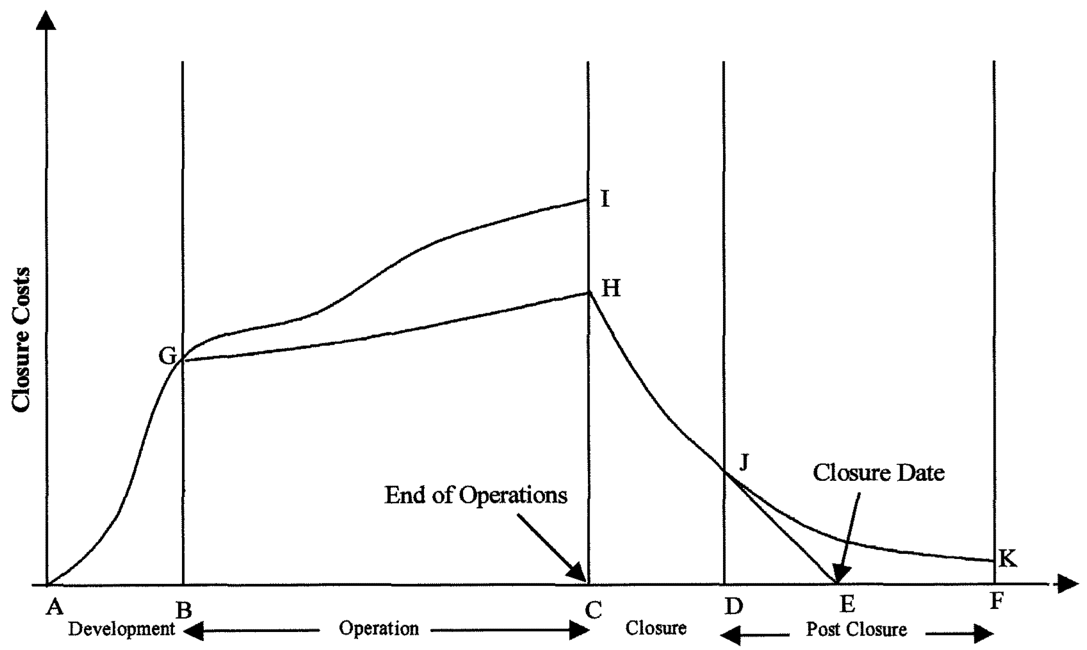

Figure 2 – Planned Closure Costs Through a Mining Project Life.

Cost Estimate

Closure cost estimates are used by mining companies to provide funds for closure and by regulatory agencies to establish financial guarantee. A cost estimate should be developed from the closure plan. The accuracy of this estimate, however, will depend upon site-specific information and data (Anderson, Orava *et al.*, 1999). However, because of the complex regulatory systems and financial instruments that exist, closure costs estimation is a difficult issue for both mining companies and regulatory authorities. Experience shows that, eventual closure costs often exceed early estimates (Dahlstrand, 1995). As an example, see Summitville Mine "reclamation" (Robinson, 2002) and the closure process at Maria Preta Gold Mine in Brazil where final closure cost was 5.5 times more than the estimated cost (Júnior and Sánches, 2002). Barnes *et al.* (1999) describe the Homestake Mining Company's experience with respect to factors that cause underestimation of closure costs which can be easily externalised for the mining industry. Usually, these factors relates to costs estimates based upon conceptual closure plans and estimates developed by companies with little experience of rehabilitation and closure.

Most mine companies fail to conduct adequate environmental investigation and research in developing detailed closure programmes. During the permit stage, regulatory agencies generally require mining companies to develop detailed environmental information. However, rarely does this environmental data collection continue to the extent required during the operation phase of mining. Economic performance considerations often delay the expenditure required for the collection and assessment of environmental data until a late stage of mining. Consequently, information is often inadequate for estimating, for example, groundwater recovery rates and quality, post-mine water quality, residual seepage quality, acid-rock potential and revegetation requirements.

Another common flaw relates to closure cost estimate developed by mine planners with little experience of mine closure programmes. The glory and prestige associated with the development of a new mine are rarely present in the closure of those same mines. The tendency of mine companies is to employ their experienced mine planners in developing new mines rather than dealing with closure. Consequently, experience levels for mine planners are heavily weighted towards new construction and mine operations. There is little emphasis upon planning for closure, because the importance of mine closure is still not well understood. This lack of emphasis translates, unfortunately, to the low priority provided to this aspect and, in addition, reinforces the lack of experienced mine planners involved with closure planning. Furthermore, current management structures within most mining companies serve to perpetuate these flaws. Generally, closure planning is the responsibility of individuals and departments having, as their primary obligation, short-term objectives. This management attitude results in long-term closure objectives being of secondary importance.

Costing of financial provisions for closure should consider an estimation of the time to closure, an estimation of the period of post-closure rehabilitation and monitoring and determination of the annual costs of post-closure activities. Moreover, within the context of closure fund estimation, mine management may wish to consider contingent costs associated with unforeseen environmental liabilities. Often, the exposure to such liability arises because of design failure, changes in regulations or litigation. Experiences have demonstrated that most estimates are vulnerable to a number of factors that cause underestimation (Barnes, Hawthorne *et al.*, 1999).

According to Barnes *et al.* (1999), the three critical components for closure cost estimation are early and continuous cost estimate throughout the mine's life; a regular and independent auditing of the closure plan and estimates; the establishment of rehabilitation targets for each mining operation based upon cost estimates. At the development stage of a mine project, initial rehabilitation and closure plans and estimates are typically adjusted to respond to regulatory requirements for mining permits and bonds. Following construction, the knowledge of the site and the experience of personnel grow as does the amount of baseline information for planning and estimation. However, because of the dynamic nature of mining, there is often hesitation in developing detailed rehabilitation and closure designs until towards the end of active mining. Experiences advocate updating plans and estimates annually through the expected last five years of a mine life (Dahlstrand, 1995).

Closure cost estimates must be based on an actual closure design using site-specific requirements; not on per area or mining rate basis. In some jurisdictions, it was common in the past to base the 'reclamation' cost on a unit of disturbed area because rehabilitation or reclamation of this area was considered the main issue (Da Rosa, 1999). Most of mine closure papers, however, clearly indicate that it is the 'closure' cost that is required for financial surety and not the rehabilitation cost (MMSD, 2001; ANZMEC, 2002; Lima and Curi, 2002). The mine closure design must include all elements of the site and not only the rehabilitation. Acid drainage concerns at a site may require special considerations such as active and or passive treatment. A complete closure design must be prepared to estimate the closure cost and it must be based on realistic assumptions about closure technologies and implementation, including the time it would take to complete at the mine site. Mine closure cost estimates are refined during the mine life as the final decisions about closure implementation, detailed land use issues, etc. become clear.

FINANCIAL PROVISION

Mine closure takes place when there is typically no return from the operation and there may be little value in the remaining assets. The objectives of providing a financial provision are to ensure that adequate funds are available at the time of closure and that the community is not left with a liability. A schedule for financial provision should be part of all closure plans. The amount provided for rehabilitation should be consistent with the degree of disturbance at any given time. The provision is typically accrued over the life of the operation, and may be varied to reflect changes in mine planning and operations. It is in the best interest of an active mining operation to develop and periodically review and update the closure plan and to modify its internal accrual process so that unexpected costs do not occur at the beginning of decommissioning. More emphasis is being placed not only on the internal accrual process but also on the external financial guarantee requirements. In order to reduce further public intervention into the accrual and security aspects of a mining operation, there needs to be a commitment to conduct these periodic assessments in a realistic manner (Mudder & Harvey, 1998).

The relevance of closure costs for financial stewardship reporting purposes is recognised by the accounting profession. Generally accepted accounting principles and practice require companies to use the accrual basis of accounting to match revenues with associated expenses (WMI, 1994). According to PricewaterhousesCoopers (1999) international accounting practices for rehabilitation costs vary from no recognition of a liability to full recognition. There is no specific International Accounting Standard dealing with the costs of closing a mine, but this issue, and the recognition of provisions in general, is being addressed by International Exposure Draft E59 - Provisions, Contingent Liabilities and Contingent Assets and a number of very similar national exposure drafts. The three most commonly used methods are: the expense as incurred method, the incremental method and the full liability method.

By using the expense as incurred method a mining company expenses all costs as they are incurred. A mining company can justify this by selling any fully written-down assets and re-work waste piles, slag heaps and tailings dams to provide cash surpluses at the end of the mine's life. In many cases this surplus offsets the cost of rehabilitation (PricewaterhousesCoopers, 1999). Alternatively, costs that were known to be incurred after the cessation of production are provided for in the concluding periods (say the last 5 years) of productive operations when the costs can be determined with more certainty. PricewaterhousesCoopers does not recommend this method because it is not in accordance with the principles of the international framework. It also notes that this method has not been commonly used in recent years.

With the incremental method a company can accrue closure costs by gradually increasing the provision over the life of the mine. The practice of estimating the future cost of rehabilitation and then building up to that cost over the life of a mine by making periodic provisions (the 'incremental' or 'rateable recognition') is adopted by many mining entities and grew out of conservative provisioning practices based on the matching concept. The main objective of this approach is to ensure that the full liability is accrued at the end of the life of mine and closure costs are allocated equitably to the periods of operation. The liability is often small, in particular in the early stages of mining, so only limited disclosures are generally provided.

Using the full liability method, a mining company provides for the total present value of the future cost of repairing past damage and other related closure costs as soon as the commitment is incurred and the amount capitalised under this method is amortised over the life of the mine. This method is not in common use (PricewaterhousesCoopers, 1999). A slightly different method is used in strip-mining, where rehabilitation is required shortly after mining is completed in particular areas. In these cases you can make an accrual during production for the cost of rehabilitation of mined-out areas. If rehabilitation costs are incurred at a similar rate to production (and not significantly in sum unpaid), a company can treat these costs as part of production costs when incurred.

FINANCIAL GUARANTEE FOR MINE CLOSURE

Increasingly, financial guarantees tend to be required for new mining operations to ensure sufficient funds for mine closure and post closure purposes. Similar guarantees are also being gradually required for mining companies already in operation. These securities are prescribed conditions of exploration and mining titles and are generally referred in the Mining Acts in relation to exploration licences, assessments leases and mining leases. Such empowering legislation was developed mainly in response to an accumulated legacy of derelict mined-out land and long-term environmental liabilities (Marcus, 1990; Miller and Eldon, 1991; Miller, 1998; Da Rosa, 1999).

Financial guarantees are quite separate from any internal accounting provision and should not in anyway counterbalance this provision. Financial guarantee is an instrument issued by a bonding company, an insurance company, a bank, or other financial institution (the issuer is called the "surety"), which agrees to hold itself liable for the acts or failures of a third party (Hayes, 1994). Financial guarantees are designed to protect the community from closure liabilities. Financial guarantee for mine closure and post closure is simply a guarantee that the closure plan will be implemented. It is for estimated costs only (Miller, 1998; Da Rosa, 1999), not an insurance against incidents.

This section deals with the determination of the amount of a closure guarantee, the most common financial instruments available to the mining companies to satisfy the regulatory agencies' current and anticipated requirements, characteristics, advantages and disadvantages pertaining to these instruments as well as the problems faced by mining companies and governments to implement such instruments. The most common instruments of financial guarantee available include trust funds, surety bonds, letters of credit, corporate guarantees and insurance. The mechanisms of arrangement a trust fund or of procuring a surety bond are beyond the scope of this section, as are the procedures of obtaining a letter of credit, purchasing insurance or providing a corporate guarantee.

A closure plan serves as the basis for regulatory agencies' determination of the amount of the financial guarantee. A guarantee should reflect the cost of closure and be adjustable, up or down, to reflect changes in proposed closure plan. This cost will frequently be higher than the cost to the title holder, because, in the event of default by the operator, the state will not be able to use site's mine production equipment and personnel, with resulting marginal cost (Hollands, 1999). In practice, however, according to Nazari (1999), permitting agencies in the U.S. have commonly underestimated closure costs by failing to account adequately for permit violations, off-site pollution, administrative costs and inflation.

The problems of implementing financial guarantees for mine closure include: governments' lack of familiarity with the use of financial surety; delays and high legal costs; lack of consistency across provincial/state governments with respect to the choice of financial surety instruments; absence of guidelines for applying the concepts of discounting, long-term obligations and calculating the amount of security required; unwillingness of government to recognise that a "softer" form of assurance may be appropriate in certain circumstances; and lack of equitable tax treatment of funds when funds are actually deposited for this purpose (Miller, 1998).

Both government and mining companies, in every instance, need a detailed estimate of what it will cost to perform all required closure activities that will have to be produced. This estimate must be as accurate as possible since it will, in effect, form the basis for determining which instrument of providing financial guarantee are actually available to a given mining company. In preparing closure costs estimates, mining companies should determine the cost of rehabilitation at a time when the extend and manner of a mine's operation would make closing the mine activities the most expensive. Government estimates should also consider the cost of hiring a third party to perform closure activities. In doing so, both government and industry will have anticipated the worst-case scenario.

In the US federal guidelines prescribed in the Department of Interior's Office of Surface Mining and Reclamation (OSMR) handbook on bond calculations recommend determining closure bond amounts using the "greatest estimated closure costs for the permit term." According to the handbook closure guaranties should also include costs factors for the following items in Table 3 (US Department of Interior, 2000).

Table 3 – Closure Guarantee Factors, after (Legislative Audit Division, 1997).

Direct closure costs	Calculated using conditions which represent the maximum closure cost.
Indirect closure costs	Contract preparation and administration costs for staff time. Calculated by project staff and site specific.
Mobilization	1 to 5 percent of direct closure cost
Contingencies	Project uncertainties and unexpected natural events, 2 to 5 percent of direct closure costs.
Engineering and Design	Redesign to reflect current conditions, 2 to 10 percent of direct costs.
Profit and Overhead	Contract profit and overhead not included in direct cost calculations, 3 to 14 percent of direct closure costs.
Closure management	Project inspection and supervision, 2 to 7 percent of direct closure costs.

Table 4 presents the principles that should be followed for governments for developing a financial guarantee policy for mine closure.

Table 4 – Financial Guarantee Principles, after Da Rosa (1999)

Closure costs	Financial guarantees must cover the mine company's costs, both rehabilitation and the post-closure monitoring period.
Liquidity	All forms of financial guarantee should be reasonably liquid.
Accessibility	Financial assurance should be readily accessible, dedicated and only released with the specific assent of the regulatory authority, so that regulators can promptly obtain funding to initiate proper closure in case of operator default.
Healthy guarantors	Regulators must carefully screen guarantors' financial health before accepting any form of assurance.
Public involvement	Regulators must give the public notice and an opportunity to comment both before the setting of a bond amount and before any decision on whether to release a bond.
No substitute	Any financial guarantee should not be regarded as a surrogate for a company's legal liability for mine closure.

Financial guarantee instruments

Financial guarantee instruments may be, and are, chosen from a large number of options. Each specific instrument may be appropriate in a given situation or set of circumstances, depending upon the financial strength of the mining company, its history of environmental performance ("track record"), the extent of the potential environmental liability and the time frame over which the liability is to be extinguished. An excellent guide to the economic consequences to companies of various bonding alternatives can be found in Hayes (1994).

Miller (1998) and Anderson (1999) examined the various mechanisms of financial guarantee as well as the circumstances that influence the selection of these. The findings stress the importance of flexibility in the selection and application of the various types of bonding. There was no recommendation for one preferred instrument that could be a universal model. Table 5 summarises the characteristics, advantages and disadvantages of some of these instruments.

Surety bonds were the most heavily instrument. However, currently there are few surety companies willing to underwrite bonds with closure requirements – an indication of the perceived risks involved. After the 11th September of 2001 terrorist attack and bankruptcy process of big companies as ENRON Corporation, many of the security companies have declined to work with mining closure guarantees because of the highest risk involved (Carlton, 2002). This scenario has been previously anticipated by Belsky (1992), which stated that mining companies will face problems to get financial surety for mine closure purposes. Surety companies are becoming more selective in their choice of clients. This implies higher premiums, higher collateral requirements, narrower coverage and low aggregate bonding limits for individual mining.

In addition, new regulations have required extensive work to be done in order to properly close a mine and, as a consequence, closure costs are on the upswing. As closure costs rise, so do required financial guarantee limits. And as bonding limits rise, the ability of both surety and mining companies to meet financial guarantee requirements diminishes. As a consequence, mining companies in the US are to pushing governments in accept self-guarantee based on company's assets.

Table 5 – Financial Guarantee Instruments

Types	Characteristics	Advantages	Disadvantages
Surety bonds	• Most heavily used instrument; • Used for at least two decades in US; • A premium is paid by the mining company to the underwriting institution that is the guarantee.	• The cost of getting it is relatively low; • Cost associated with putting it are expensed as a tax deductible item; • Once in place only a minimal amount of administration is required; • Many ways of initiating and releasing bonds trough phased implementation and phased release.	• Often a Letter of Credit is required to back up the bond, which makes it more expensive; • Its availability may be restrict by a company's credit and its environmental risk; • The full face value of the surety may be required.
Letters of Credit	• Similar to a surety bond; • The content of a LC should reflect the terms and conditions agreed between a company and the government with respect to a specific closure plan.	• Low initial cost (about 1% per annum of the face value; • Cost associated with opening a LC are expensed as a tax deductible item; • Once in place only a minimal amount of administration is required.	• Issued by a bank and usually for a larger sum of money than originally estimated for closure; • Fee paid to the lending institution to cover the transaction (even if draw-down does not occur); • The availability of a LC may be restrict by a company's credit and its environmental risk; • Issued for a period of one year – short-term solution for a long-term problem; • Reduction of the company borrowing power.
Cash Trust Funds	• The funds must be structured in such a way as to give reasonable assurance that sufficient funds will be available to meet expected closure costs; • It is highly desirable that the income earned by the fund be tax protected until it is withdrawn.	• The company has control over its fund, since any surpluses created or earned should be returned to the company; • The company have the incentive to ensure sound management of the fund; • Are more visible and often better understood by government and the public than other alternatives.	• Great uncertainty about the size of the fund in view of the long time frame involved; • If large amount is required a transition period is necessary to allow time to the company to build up the required financial guarantee.
Insurances	• Special form of surety bond; • The premium paid will be a function of the estimated closure cost with actuarial calculations to annual pay-out levels and the total amount of the insurance.	• May require smaller up-front cash commitments than a cash trust fund; • Premiums would be tax deductible; • Less administration is required than with a cash trust fund.	• Initial premiums may be very high to ensure substance of the insurance; • In addition to premium amounts there could be taxes and insurance brokerage fees; • A new, not well tested guarantee instrument.
Self-guarantees	• Also known as corporate guarantee or self-insuring; • Based on an evaluation of the assets and liabilities of the company and its ability to pay the cost of closure requirements.	• Financial instrument of choice for a mining company.	• Require long history of financial stability and an annual financial statement prepared by accredited accounting firm; • Gaining access to assets may be problematic in the case of firms facing bankruptcy.

Source: (Miller, 1998; Anderson, 1999)

The mining industry, however, should require that governments specify an approved selection of financial guarantee instruments and discuss with companies which instrument(s) are most appropriate to the specific closure situation. The choice of instrument should recognise the age and duration of the total obligation, what has been spent to date and the relative risk of default.

The different instruments should be distinguished on the basis of such circumstances as the following:

Soft guarantees (e.g. corporate guarantee) can be used where the risk of default is low; the closure plan and cost estimate is independently confirmed (i.e. the technical risk is low); the closure is of a short-term nature; and the company has appropriate financial strength to support the guarantee, such as an investment grade rating (Miller, 1998).

Hard guarantees (e.g. letters of credit, trust funds) can be used where the risk of default is high; the timing of the closure is imminent; the closure must be continued over the very long term and the company does not have an investment grade rating (Miller, 1998).

COMPLETION CRITERIA

An important issue during planning for closure is a thorough knowledge of the completion criteria. According to an OECD definition, completion criteria are performance indicators, which attempt to measure the distance from ambient conditions to a stated goal (OECD, 1998). Mine completion criteria are an agreed standard of performance that demonstrates successful closure of a site. Thus, it is vital that the post-mining use is clearly identified and the socio-ecological conditions, which define this objective, are adequately described. In addition, as the ultimate post-mining use may take decades to be achieved, it is imperative that the completion criteria reflect the initial post project structure and trends, rather than projected end state. Completion criteria establish the actions required to meet the closure objectives as well as the post-closure monitoring and maintenance necessary to show the success of a mine closure programme. Criteria need to be established to enable closed-out sites to be returned to the State on an equitable and cost-efficient basis to both government and industry while ensuring long-term protection of the environment (WMI, 1994).

Completion criteria are the basis on which successful rehabilitation is determined, and should be developed in consultation with stakeholders. This ensures that there is broad agreement on both the end land use objectives and the basis for measuring the achievement of that objective. It is commonly accepted that completion criteria need to be specific to the mine being closed and reflect the unique set of environmental, social and economic circumstances of the site (Hollands, 1993; Waggitt and McQuade, 1994; Jarvis, 1998; Danielson and Nixon, 1999). Completion criteria should be flexible enough to adapt to changing circumstances without compromising the agreed end objective. This provides certainty of process and outcome (relinquishment of tenement when the conditions have been met). There should be an agreed process for the periodic review and modification of completion criteria in light of improved knowledge or changed circumstance. They should be developed and agreed with all stakeholders and, where possible, should be quantitative and capable of objective verification. Legislation on this matter should be non-prescriptive and based on agreed objectives and clearly understood by and acceptable to the industry as a minimum standard, which best practice should exceed wherever possible (Jarvis, 1998).

As the agreed post-mining land use may take years or even decades to achieve, a set of specific performance indicators should be developed to measure progress in meeting the completion criteria. Industry standards can be established at a national or regional level as a basis for the development of more detailed site-specific standards. Correctly chosen, the environmental indicators will show whether the ecological processes which will lead to successful rehabilitation are trending in the right direction. This will enable early intervention where trends are not positive.

RELINQUISHMENT

Despite the magnitude and complexity of mine closure, over time most operators will be able to satisfy their obligations under Federal and/or State regulations. The expectation is that the Responsible Authority will accept the operator's performance and release the surety, and accountability will revert to the State or a subsequent land owner. However, while it is one thing to expect to be released from mine closure obligations, it is quite another to expect to be discharged from further liabilities under broad environmental and civil laws (Williams, 1993).

From the perspective of governments a responsible authority should be identified and held accountable to make the final decision on accepting closure. The Responsible Authority (usually State Department of Mineral Resources or equivalent) will make a judgement on the achievement of the agreed completion criteria after consultation with other involved regulatory agencies, including the future land controller. All release criteria are predicated on the prescribed or agreed post-mining land use. A sufficient period of time should have elapsed to demonstrate the stability of the site. For revegetated areas, this may require verification that the vegetation is, or is trending towards, a self sustaining status. Potential impacts on groundwater may also take several years of monitoring to establish or refute. The site should not endanger public health and safety, should alleviate or eliminate environmental damage, and allow a productive use of the land similar to its original use or an acceptable alternative. A site requiring active maintenance is unlikely to be acceptable to government agencies. Release of securities and bonds may be progressive, and reflect the progress of rehabilitation. To facilitate this process, governments may wish to consider additional incentives for timely completion of closure commitments. When the responsible authority has agreed to relinquishment of the site, the management and maintenance of the site would rest with subsequent owners or the State (Biggs, 2000; Clark, Naito *et al.*, 2000; ANZMEC, 2002).

It is advisable that records of the history of a closed mine site should be preserved to facilitate future land use planning. These records, while potentially of no further use to the company that once operated the site, are valuable to governments and potential future land users (and stakeholders). The retention of mine records is important because they provide a history of past developments, information for incorporation into state and national natural resource database and the potential to improve future land use planning and/or site redevelopment. Records are invaluable to any potential redevelopment of the site, particularly in assessing the suitability of proposed future land uses that are not consistent with the agreed future land use at the time of mine closure (Dahlstrand, 1995; ANZMEC, 2002).

CHAPTER 4 - MINE CLOSURE POLICY, LEGISLATIONS AND REGULATIONS

INTRODUCTION

It is the purpose of this chapter to address the key components, particularly of policy, legislation and regulations, of government action that are required to ensure comprehensive mine closure and sustainable development following closure. The discussion begins with an overview of the Brazilian legislation pertaining to mining, the mining code, environmental laws and regulations applied to mining. Following, results of an analysis of some Plans for Rehabilitation of Degraded Areas (PRAD) are presented in order to assess the quality and importance of these plans for a comprehensive mine closure programme. This is followed by an overview of mine closure policy, legislation and regulations in a number of selected countries and an assessment of the evolving nature of government responsibilities with regard to mine closure. This overview serves as a base to discuss the main problems facing mine closure in Brazil and to propose the increasing range of issues that must be accounted for in the Brazilian policy, legislation and regulations on achieving comprehensive mine closure and sustainable development.

OVERVIEW OF BRAZILIAN LEGISLATION GOVERNING MINING

The mining industry in Brazil is very diverse in terms of type of ore produced and the size of the companies that are active in the sector. Mining industry contribution to country's GDP is about 2%, however, it rises to over 9% of GDP when the transformation of its primary products into metals and alloys, cement, ceramics, fertilizers, glass, chemical compounds, etc are taken into account (Chambers and Machado, 1999; DNPM, 1999; Machado, 1999; Neto, 1999).

In Brazil, operating mines, producing about 80 mineral substances, are classified as large (run-of-mine higher than 1 million tons per year), medium (run-of-mine between 100 thousand and 1 million tons per year) and small (run-of-mine between 10 thousand and 100 thousand tons per year) as shown in Figure 3 (Gurmendi and Barbosa, 1999). The

Southeast region of Brazil contains 54.5% of the total mines, the rest being distributed in the four other regions. Minas Gerais State is the most important mining State holding 50.6% of the largest mines and 46.5% of the medium ones. Considering the distribution by mineral substance of the large-scale mines, 44.9% relate to metals with iron ore mines representing 60% of them. Medium mines have a more diversified mineral substance distribution. The Southeast region (the most populated) contains 51.6% of the small mines. Seventy-two percent of these are for the extraction of materials for construction. Figure 4 shows the contribution of the mineral substances to the value of Brazilian mineral production. Iron ore represents 17.96% of the metallic minerals production (the second Brazilian exporting commodity) and oil 36.91% of the energetic substances production. If oil and natural gas is not included, the importance of iron ore to the Brazilian mineral production value becomes higher than 28.0% (DNPM, 1999).

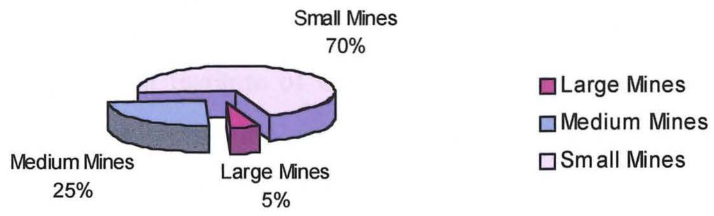

Figure 3 – Size Distribution of Brazilian Mines (DNPM, 1999).

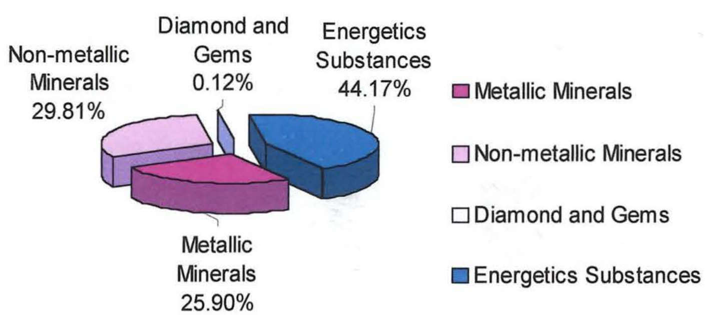

Figure 4 – Contribution of Mineral Substances to Brazilian Mineral Production (DNPM, 1999).

Environmental Laws and Regulations

In Brazil environmental protection is a matter of constitutional law. The Brazilian Constitution of 1988 has an entire chapter dedicated to the preservation of the environment. Article 225, specifically, guarantees the right of all citizens to 'an ecologically balanced environment' and that both the government and civil society have the duty to preserve it for present and future generations. In the following section a chronology of the environmental policy and legislation developed in Brazil since the United Nations Conference on the Human Environment, held in Stockholm, Sweden, in 1972 is presented.

Chronology of the Environmental Policy and Legislation in Brazil

1973 – The Federal Law 73,030 created the National Special Secretary of Environment, which after unification with other governmental bodies responsible for forestry and fishing became the Brazilian Institute of the Environment and Recuperation of Natural Resources (IBAMA). IBAMA is the executive agency of the Brazilian Ministry of Environment, the Amazon and Water Resources.

1980 – The Federal Law 6,803 established the concept of industrial zoning for areas of critical pollution. Such areas were then conditioned by approval of environmental impact statements (Kaufman and Moreland, 1993; La Rovere and d'Avignon, 1995; Parizotto, 1995; Amaral, 1997).

1983 = The Federal Law 6,938 established the national environmental policy and created the National Environmental Council (CONAMA) as an advisory agency in the executive branch. With representatives from different government agencies, private sector and civil society (through NGOs elected on a regional basis), CONAMA is the forum in which Brazilian environmental policy is officially formulated.

1986 – CONAMA established the regulation which fixed basic criteria and general guidelines for the environmental impact assessment process in Brazil through its "Resolution 001". Since then, submission of an environmental impact assessment (EIA) and its synthesis report on environmental impact (RIMA) have become obligatory for licensing and for projects involving substantial environmental impacts. The review, evaluation and approval of environmental impact assessments is the responsibility of the regional agency dealing with environmental planning in each state of the Brazilian Federation, as well as the issuing of corresponding licences (La Rovere and d'Avignon, 1995; Amaral, 1997).

1989 – A Federal Decree required companies to submit a Plan for Rehabilitation of Degraded Areas by mining activities as part of the licensing process. Mines operating at the time the 1989 Federal Decree became effective were also required to submit PRADs within a 180 day period. To date, PRAD is a chapter within an EIS.

1998 – Federal Law 9,605 (Law of Environmental Crimes). Under this law administrative, penal sanctions and penalties for misconduct and activities that cause potentially harmful impact on the environment may be imposed on companies, directors and operators of companies as well as auditors, managers or legal agents, who, despite knowing about the crime, allow the misconduct instead of preventing it (IBAMA, 1998; Carvalho, 1999; Onishi, 1999).

The Mining Code

Exploration and exploitation of mineral resources in Brazil are regulated in the Mining Code of 1967. The regulations and corresponding legislation, subject only to the amendments and innovations introduced by laws subsequent to the 1988 Constitution. The Mining Code defines deposits and mines, sets requirements and conditions for obtaining authorisations, concessions, licence and permit, explains the rights and duties of the holders of mining rights, regulates cases for the cancellation, forfeiture and rescinding of mineral rights and regulates other aspects of the mining industry. It also defines the competence of the specific government agency within the Ministry of Mines and Energy (MME) namely the National Department of Mineral Production (DNPM), with respect to the management of mineral resources and the supervision of mining activity.

MME is the federal branch responsible for coordinating and formulating Brazilian mineral policy. It has under its jurisdiction the government agencies, federal public companies and regulating agencies, private and public joint stock companies. DNPM is the agency within MME that has the objective of planning and fostering the exploration and exploitation of mineral resources. DNPM actions are decentralized through its regional districts, with offices in the capitals of all the states of the federation.

A mining licensing process runs in parallel in the DNPM and in the environmental agency. Once the legal and regulatory requirements are met and the EIA is approved by the environmental agency, the mining concession is granted by the Minister of Mines and Energy, through a Mining Rule, which grants the deed-holding company rights and obligations (IBRAM, 1992).

Environmental Legislation Governing Mining Activities

The fundamental principles governing the compatibility of mining activity with environmental protection are outlined in the 1988 Constitution, which defines the measures the government can take to achieve this objective and also the obligations of the mining company. Article 225 of the Constitution stipulates that it is the responsibility of public authorities to 'request a prior environmental impact assessment, to which publicity will be given, under the law, for any installation of work or activity which may be a potential cause of major environmental degradation'. Public authorities must also 'control the production, marketing and use of techniques, methods and substances which endanger health, quality of life and the environment'.

As a result of such constitutional conditions, the exercise of mining activity in Brazil is subject to two specific government instruments of control, concerning the potential risks of damage to the environment as a result of mining. These are the Environmental Impact Assessment (EIA) and the Environmental Licensing (LA). Referring to mine closure, it only prescribes that 'whoever exploits mineral resources is obliged to rehabilitate the degraded environment, using a technical solution legally requested by the competent public agency' (DNPM, 2000).

The EIA is required for obtaining an environmental licence to any activity exploiting mineral resources. The EIA requirement applies to mining projects of any mineral substance, unless for mineral substances of immediate use in civil construction such as sand, gravel, stone and other construction materials, when presentation of an EIA may be not necessary. In this event, the mining company must submit an Environmental Control Report (RCA), in accordance with the guidelines of the competent state environmental agency.

Obtaining an Environmental Licence (LA) is obligatory for locating, installing or expanding and operating any mining activity subject to the concession mining system or licensing. Such licensing is regulated by Federal Decree No. 99,274 of 1990, which authorises the state environmental agency to issue and control the licences. The types of environmental licences required are named a Previous Licence (LP), an Installation Licence (LI) and an Operating Licence (LO) (IBRAM, 1992).

A Previous Licence (LP) is awarded for the mining project's preliminary planning stage and contains the basic requirements to be met during the locating, installing and operating stages, in accordance with the municipal, state or federal plans for use of soil. Such requirements must meet the regulations and standards present in the general guidelines for environmental licensing issued by the National Environmental Council (CONAMA), CONAMA Resolution No. 009 and No. 010 of 1990, for all mineral substances except for minerals for civil construction. In addition, the criteria established by the state environmental agency, in the scope of its competence and area of jurisdiction, must be met if they do not conflict with those at the federal level. The Mining Plan and the EIA are technical documents required for obtaining a Previous Licence, whose legal procedure is concurrent with the request for a mining concession.

An Installation Licence (LI) authorises the start of a mining project implementation, according to the specifications in the approved Environmental Control Plan. An Operating Licence (LO) authorises, after necessary confirmation, the start of the licensed activity and functioning of its pollution control equipment and installations, according to those provisions set out in the Previous and Installation Licences.

RESULTS OF THE PRADS ANALYSIS

In Brazil, the basic obligation imposed on the mining concession holder, related to mine closure, is to rehabilitate the mined area according to Plan for Rehabilitation of Degraded Areas (PRAD) approved by the competent environmental agency. The rehabilitation requirement for PRAD uses the basic worldwide statement that the site must be left in a state suitable for, or appropriate to, the established or agreed final land-use. Generally, statutory requirements are generic and narrow. Those required for a PRAD state: "the PRAD must consider the suitable technical solution visualized by the mine company to rehabilitate the soil, eventually degraded by mining activity, for future use" (IBRAM, 1992; DNPM, 2000). An approved PRAD can be reviewed or altered later, with the agreement of the competent environmental agency, to incorporate technological innovations or more suitable alternatives because of the development of the mining work.

In order to assess the quality and importance of the PRADs for mine closure purpose, twenty PRADs stored in the Environment State Foundation – Minas Gerais (FEAM) were analysed. First, PRADS were compared to each other to verify the consistency of their contents and the methodology employed in their preparation. Second, PRADs for specific ore/type of mine were compared each other (i.e. PRADs of iron ore mines, gold mines, manganese ore mines, and aggregates). Finally, PRAD's contents were compared with typical contents of a closure plan to establish the similarities and differences between the plans. For the purpose of this study were chosen PRADs from mines in the early stage of closure. Following is a summary of the main results obtained from this assessment.

Most of the large mines in Minas Gerais State, now in early closure, were already in operation before the enactment of the 1989 Federal Decree. Despite the good quality of environmental data available at some mines, the overall quality of the PRADs produced is questionable and many faults were observed on them. In general, these are related, firstly, to the lack of previous knowledge about ecosystems and rehabilitation practices. This made it impossible to conduct good surveys in the short time required for the elaboration of a PRAD. Secondly, in 1989, mitigation measures were not described in detail. Indeed, for new PRADs there is still no clear institutional responsibility concerning financial resources needed for implementation of a mine site rehabilitation. Thirdly, most multidisciplinary teams of consulting firms responsible for producing PRADs rarely follow an interdisciplinary approach and, even now, are still not truly independent of project proponents, who sometimes try to minimise the cost of assessment by limiting its scope. Finally, in 1989 there was no public participation due to various factors such as lack of time and a lack of organization on the part of civil society involved in the process.

Most of these large mines are in the early stage of closure, therefore, it is expected that their PRADs could be used as guidelines for both mining companies and government to establish a mine closure programme. However, this is not the practise followed by both operators and the government. The main reason is that due to lack of financial and human resources of the environmental agencies when PRADs were submitted, they were not analysed and are now stored in the state agencies. They have been used only as source of research especially for academic purposes. PRADs or mine closure planning cannot be done at one point in time and "put on a shelf". It is an ongoing, dynamic process, which may span many decades, during which many variables will certainly change, including the political context, legal systems and the nature of industry-specific legal controls.

By comparing these PRADs it was possible to see the copy and paste process that many consultancy firms and consultants used on PRADs' preparation. This process is evident when PRADs produced from analogous mines, ores and regions are compared. Topics related to description and evaluation of impacts and proposed mitigation measures are quite similar. It could be easily observed that most PRADs were perfunctory rather than thorough and not conducted on a site-specific basis. They were only prepared to comply with the law. In addition, on the time PRADs were prepared most of the companies did not have an environmental management system in place. In other words, most of the mines were not (most still not) designed and operated with focus on closure outcomes.

The development of a Closure Plan needs to take into account both the legal requirements and the unique environmental, economic and social properties of the operation. Outlined below in Table 6, (column 1) are the typical contents of a Closure Plan, which vary depending on individual circumstances. Column 2 indicates the contents similarities (√) and differences or absences (X) of a PRAD to a typical closure plan contents.

Table 6 – A Comparison of Contents of a Closure Plan and a PRAD

Closure Plan	PRAD
• Introduction & Project Description	√
– Land tenure	√
• Objectives of Closure	X
• Baseline Environmental Data	√
• Legal & Other Obligations	√
– Key statutes & regulations	√
– Responsible Authority	√
– Regulatory instruments	√
• Stakeholder Involvement	X
– Stakeholder identification	X
– Community consultation	X
• Risk Assessment	X
– Existing legacies	X
– Future risks	X
– Cost/benefit analysis	X
• Closure Criteria	X
• Closure Costs	X
– Provisions	X
– Securities	X
• Closure Action Plan	X
– Human resources/responsibilities	X
– Progressive rehabilitation	√
– Decommissioning	√
– Remediation	√
– Geotechnical assessment	√
– Landform establishment	√
– Revegetation	√
– Aesthetics	√
– Heritage	√
– Health & safety	√
– Post-closure maintenance & Monitoring	X
• Monitoring	√
– Survey (remaining structures & areas of contamination)	√
– Documentation/reporting/records	√
• Tenement Relinquishment	X

Following is a summary of the major points observed in a comparison between PRADs and closure plan contents.

1 – Objectives

In general terms, PRADs objectives are quite similar to closure plan ones. Broad PRADs' objectives are to protect the environment, public health and safety by rehabilitating a mine site to a state suitable for an agreed post mining use. However, the means to reach these are quite different when contents are compared.

2 – Stakeholder Involvement

It is generally agreed that, in principle, public involvement in mining-related decision-making and management processes is an important factor in enhancing the legitimacy of the industry, in developing public trust in the ability and desire of mining companies to conduct their business in an environmentally responsible manner, and in improving the quality of the decisions being made regarding environmental management (EPA, 1995d; Hannan, 1998; Alberts and Grasmick, 2000). Stakeholders are those parties with the potential to be affected by the mine closure process. They are distinct from Interested Parties, who have an interest in the process or outcomes of mine closure. Identifying key stakeholders and interested parties, and developing a good relationship with them, is fundamental to a successful closure process. The objective is to enable all stakeholders to have their interests considered during the mine closure process. Although some PRADs analysed make reference to community directly involved with the mine operation, in most of them the process of stakeholder identification and community consultation were not reported.

3 – Risk Assessment

A risk-based approach for mine closure planning should reduce both cost and uncertainty. Current trends in closure planning involve technical review and analysis of risk and cost benefit in both engineering and environmental terms. The advantages of a risk-based approach to closure planning lie in the quantification of subjective factors and the analysis of uncertainty related to both design performance and cost (Morrey and Van Zil, 1994; Morrey, Van Zil et al., 1995; Morrey, 1999). The objective of a risk-based approach is to reduce both cost and uncertainty. No one of the PRADs analysed used a risk assessment approach.

4 – Closure Criteria

Due to the lack of closure criteria in Brazil, most PRADs do not specify nor mention a set of indicators that will follow to demonstrate the successful completion of the rehabilitation plan. Both Brazilian government and mining industry lack these criteria.

5 – Closure Costs

The objective of financial provision and guarantees for mine closure purpose is to ensure the cost of closure is adequately represented in company accounts and that the community is not left with a liability. Most of the PRADs analysed do not include rehabilitation cost estimation as well as do not demonstrate that a financial provision has been provided. In addition, as the regulatory system does not require any form of guarantee there is a risk of further liability to the community.

6 – Closure Plan Action

Most of the PRADs analysed refer to mine rehabilitation only as a process of revegetation. Three PRADs, however, include in the action plan topics as human responsibilities, progressive rehabilitation, decommissioning, geotechnical assessment and landform establishment. On the other hand, most of them do not include a post-closure maintenance and monitoring programme.

7 – Relinquishment

The final objective of a closure plan is to reach a point where the company has met agreed completion criteria to the satisfaction of the Responsible Authority. Despite the magnitude and complexity of mine closure, over time most operators will be able to satisfy their obligations under Federal and/or State regulations. The expectation is that the Responsible Authority will accept the operator's performance and release the surety, and accountability will revert to the State or a subsequent land owner. However, while it is one thing to expect to be released from mine closure obligations, it is quite another to expect to be discharged from further liabilities under broad environmental and civil laws (Williams, 1993). All release criteria are predicated on the prescribed or agreed post-mining land use. Therefore, as Brazil lacks closure criteria there is no mention about the relinquishment procedure on the PRADs analysed.

In summary, in most nations mine closure programme, as detailed in an overall feasilibility study, a mining plan, an EIA or an environmental mining plan are normally preconditions for acquiring a mining license and *de facto* the most common means by which government ensure comprehensive mine closure. In Brazil, PRAD is part of the EIA process and by this one can understand PRAD as a conceptual closure plan. However, as demonstrated PRADs are far from this.

MINE CLOSURE LEGISLATION AND REGULATION

The concepts, definitions and issues surrounding mine closure are rapidly evolving in terms of the perceived scope and responsibility of the major interested groups, for example government, industry, impacted communities and other stakeholders such as non-governmental organisations (NGOs), inter-governmental organisations (IGOs), leading institutions and other components of civil society. The common theme of most of mine closure definitions is that rehabilitation of an area impacted by mining precludes further environmental damage and allows for alternative use. In essence, mine closure is largely regarded by industry and, until recently by most governments, as primarily an environmental issue. This perception, particularly on the part of many governments is changing rapidly.

From the perspective of governments mine closure presents a complex mixture of environmental, social, economic and development issues. The government must ensure that (1) industry has adequately recognised and prepared for over the life of the mining enterprise and (2) that the closure plan is conducted to the satisfaction of the communities involved, other major stakeholders and government at all levels. Governments are now realising that they have the most direct responsibility for defining and ensuring comprehensive mine closure within the broader context of the issues of 'social and economic equality and sustainable development' (Miller, 1997; Ricks, 1997; Ackermann, 1998; Cooney, 2000; Eggert, 2000; Khanna, 2000; MMSD, 2001). This recognition of a broader context of mine closure has greatly expanded the scope of government responsibilities and needed actions.

The perspective of the mining industry is normally somewhat less global than that required of government. Obviously, responsible industry does not see its role as being exclusive of the broader concerns addressed by governments but rather that its role is more specific to achieving the major mine closure objectives (Biggs, 2000). Clearly, the mine closure objectives set forth by industry are primary focused on achieving long-term mitigation of environmental impacts, land rehabilitation and on achieving a final release of liability for the site (MCA, 1997; Jarvis, 1998). These objectives are considered more focused than those of the local community.

Communities coupled with a mine site and/or its support facility view the issues surrounding mine closure in the broadest context as they are most directly impacted by the actual closure of a mine and by the remnants (open pit, underground openings, infrastructure, waste piles and tailings dams and social change) that will continue after closure. Although the communities concerns encompass those of government and industry, their priorities may vary considerable and be more heavily focused on the development of alternative modes of economic and social development that will replace those provided by a mine during its life (Anderson, 1998; Hannan, 1998; McMahon, 1998; Lahiri-Dutt, 1999; McMahon and Strongman, 1999; Alberts and Grasmick, 2000)

It is the purpose of the remainder of this chapter to review the key components, particularly of policy, legislation and regulation in a number of selected countries where government action are required to ensure comprehensive mine closure and sustainable development following closure. The author concludes with a series of recommendations for the government actions in Brazil, related to the development of appropriate policy, legislation and regulations for mine closure, which promote sustainable development.

Comprehensive mine closure and all that it involves would basically be part of any mining enterprise, however, past history and present practices in many countries clearly demonstrate that this is not the case. Therefore, in many countries where mining is a major (sometimes only a minor) activity have put in place policies and legislation that provide for comprehensive mine closure. Compliance with these provisions is often a pre-condition of acquiring a mining licence and *de facto* the most common means by which government ensures comprehensive mine closure. Table 7 summarises the provisions pertaining to mine closure required in Australia, Brazil, Canada, UK, South Africa and US.

Table 7 – Provisions for Mine Closure in some Countries and their Respective Provinces, Territories and States, After (Clark, Naito et al., 2000).

Country, State or Province	EIA required before lease	Provisions for rehabilitation	Guarantee requirement	Provisions for abandonment	Provisions for non-compliance
Australia					
New South Wales	√	√	√		√
Northern Territory	√	√	√		√
Queensland	√	√	√	√	√
South Australia	√	√	√	√	√
Victoria	√	√	√	√	√
Western Australia	√	√	√	√	√
Brazil	√				
Canada					
British Columbia	√	√	√	√	√
Manitoba	√		√		√
New Brunswick	√	√	√		
Northwest Territories	√	√	√		√
Nova Scotia	√	√	√	√	√
Ontario	√	√	√	√	√
Quebec	√	√			
Saskatchewan	√	√			
Yukon Territory	√	√	√		√
South Africa					
United Kingdom	√	√	√	√	√
United States					
Alaska	√	√	√		√
Arizona	√	√			√
Califórnia	√	√		√	√
Montana	√	√	√		√
Nevada	√	√	√		√
New México	√	√			√
Utah	√	√		√	√
Washington	√	√			√

Most of the countries presented in Table 7 and/or their individual provinces or states have enacted and implemented actual mine closure laws, for example, the UK (Department of the Environment, 1996), most provinces of Australia (Brooks, 1997; ANZMEC, 1999; Clark, 1999; Biggs, 2000; Clark, Naito et al., 2000; ANZMEC, 2002; EPA, 2002) and Canada (Ontario, 1995; Overholt and Downs, 1996; Environmental Mining Council of BC, 2001; Manitoba, 2001a), South Africa (Richter, 1993; Champigny and van Heerden, 1995; DME, 2000a) and some states of the US (O'Bryant, 1995; Smith, 1995; Jones, 1996; Danielson and Nixon, 1999). In most of them, mine closure regulations occur either within the mining law or within specific environmental legislation that is applicable to mining. In the latter case the requirement is that and EIA or EIS be prepared for development projects that are anticipated to have great environmental impact (e.g., Brazil).

Most of these closure systems incorporate three maxims: the polluter pays, which means that mining companies must be responsible for all clean-up costs; the precautionary principle, which means that it is imprudent to proceed with a development of a mine until the consequences of that development are clear; and sustainable development, which can be reached if the mining industry maximises the environmental, economic and social returns provided from the development of minerals resources.

From Table 7 it can be observed that most nations have adopted guarantee (surety) procedures to provide for the appropriate closure of existing and planned mines. The requirement for guarantees to be posted is a key element in achieving comprehensive mine closure because it ensures that there will be adequate financial resources available to the government, in case of failure or bankruptcy of the operator, to carry out closure successfully. Regardless of the approach or the requirements, however, mine closure plans vary greatly among and within individual countries, as do the requirements for bonding or other surety instruments to ensure that closure is considered in every detail.

The process of closure, the release of company responsibility of a site and the rights of landowners and communities around the mine are all determined by legislative requirements. These issues are addressed differently in various countries. In general, most of the countries presented in table 7 the scope and nature of resulting mine closure issues have been quite similar as have been their responses at national and subordinate (province, state and territory) levels of government.

Although there are many similarities at the national level and subordinate levels of governments there are many differences, particularly between the subordinate levels of government, in how to deal with the specific aspects of mine closure. The greatest differences are with respect to the level of specific policy and legislation that is in place for the abandonment and post-closure responsibilities. In cases of large-scale impact from abandoned mine, as an example of the Summitville Mine (CDPHE, 1998; Gobla, 1999), the national government is expected to provide the majority of financial and technical assistance for clean up. In the US this is undertaken under the Comprehensive Environmental Response Compensation and Liability Act – better known as the 'Superfund' (Biggs, 1990). Another example regarding post-closure responsibilities is the liability issue in Australia, which differ considerably from province to province, as shown in Table 8.

Table 8 – Details of Liability in Different Territories, after (Waggitt and McQuade, 1994; Clark, 1999)

Territory	Liability
New South Wales	The coalmine leaseholder remains liable. In the case of other mines, the landowner is liable.
Northern Territories	Once the mining company has renounced the site, liability rests with the land titleholder.
Queensland	Liability is with the landowner, but mining companies may be held liable under the Conservation Act if subsequent problems arise.
South Australia	Liability lies with landowner, unless another arrangement has been agreed at closure.
Tasmania	Crown is liable after the discharge of corporate liability with the discharge of lease and closure.
Victoria	Liability rests with the landholder, but the mining company can be prosecuted if problems related to mining occur and additional cleanup is required.
Western Australia	Liability lies with the landowner or Crown.

Apart from Queensland and Victoria where liability lies with the mining company, the position during the mine operational phases over the rest of Australia is that liability falls on the landowner or leaseholder. In most instances at closure, the mining or mineral lease is relinquished or extinguished and the landowner, either state or private, resumes liability.

According to Clark, Naito *et al.* (2000) the differences that do exist among nations and within subordinate levels of government are largely attributable to two major factors. First, the presence or absence of well-articulated national policies and priorities with respect to mine closure issues determines, to a large extent, whether or not subordinate government levels will feel obliged to develop their own policy and legislation. This is well-defined in Australia (Biggs, 2000; Clark, Naito et al., 2000; ANZMEC, 2002) and in UK the Department of the Environment has issued Mineral Policy Guidance Note 7 entitled 'The Reclamation of Mineral Workings' as guidance to all local planning authorities for overall planning for mine closure (Department of the Environment, 1996). It is less well-defined in Canada and US. For example, coal mining in the US is covered by federal laws, while metallic mines are subject to state legislation (Danielson and Nixon, 1999). Second, the differing levels may also be a function of the continuing prevalence within parts of industry and government that issues of mine closure are primary related to, and cease, with rehabilitation (the Brazilian case).

Although mineral resources are considered the property of the State, the responsibility for the enactment, implementation, monitoring and for ensuring compliance of specific mine closure policy and legislation is largely the responsibility of the subordinate levels of government may be either general or specific. As an example of the latter, the province of Ontario, Canada has drafted, under provincial Mining Act, the 'Mining Development and Closure Under part VII of the Mining Act' (Doran and McIntosh, 1995; Ontario, 1995; Boraussa, 1996; Cowan, 1996; Cowan, 1999). This Act deals in detail with all issues of mine closure. Similarly, the State of Nevada, US in 1998 enacted Nevada Administrative Statute NAS 519-A entitled 'Reclamation of Land Subject to Mining Operations or Explorations Projects' that covers a range of mine closure issues encountered over the life of a mining enterprise (Clark, Naito et al., 2000).

Despite the variations in policy and legislation, the trend in all nations listed in Table 7 is most certainly toward developing a more comprehensive approach, at all levels of government, to ensure acceptable mine closure. These concerns are also shared by the mining industry by taking itself a more active role in defining satisfactory guidelines for mine closure. The most recent and comprehensive example of this is the issuance of the "Strategic Framework for Mine Closure" prepared by the Australian and New Zealand Minerals and Energy Council (ANZMEC, 2002).

The Role of the Brazilian Government in Mining Closure

The goal of any government and mining project should be to mitigate or prevent the impacts resulting from mining and upon closure to have put in place the necessary prerequisites for post-closure sustainable development (Clark, Naito et al., 2000). To do this it is imperative that government, industry and involved stakeholders work closely together from the earliest stages of a mining project (exploration) to mine closure and beyond (Miller, 1997; Biggs, 2000). The responsibilities of the various actors involved in achieving sustainable development in a post-mining site and region are quite different.

According to Clark and Naito *et al.* (2000) local communities have the first responsibility in achieving sustainable development, second is the national government which will have conflicting claims on its diminished resources and last, industry which will have discharged its responsibilities and will have left to undertake development elsewhere. The government, however, as the owner of the nations resources, has the primary responsibility to develop, implement and ensure compliance with an overall programme of activities that will provide for sustainable development during and after mine takes place (NRC, 1996; Harries, 1998; Davy, 1999).

The scope and complexity of the considerations that the Brazilian Government must accommodate in developing a comprehensive mine closure policy and programme largely accounts for the fact that the country does not have provisions for mine closure in its laws as shown in the next section.

Mine Closure Legislation and Regulation in Brazil

National Department of Mineral Production (DNPM) is responsible for granting mining title and dealing with cases of abandonment, surrender, cancellation, forfeiture or termination of a mining claim. On the State level, the environmental agency requires an environmental impact assessment (EIA) that has included a plan for the rehabilitation of degraded areas (PRAD). However, this process does not ensure that a mine company's PRAD will be implemented, nor guarantee satisfactory site rehabilitation at the end of the mine life cycle, especially as cash balances are frequently negative at this stage.

Legislation and the ability of the authority to implement legislation are central to drive mine closure practice. In Brazil, a mine closure legislation and regulatory system do not exist yet. At present, the Brazilian Department of Mineral Production, the Brazilian Institute of Mining (IBRAM) and some environmental agencies are working together on a proposal for legislation and regulatory system (Riter, 1999; Tunes, 2002). Considering the Brazilian environmental background provided early in this chapter, the main problems facing mining closure are:

1 – Lack of legislation and regulatory system and general guidelines

Brazil lacks co-ordination at the Federal, State and Local governments to deal with closure. This has caused confusion and a lack of a cohesive approach to managing the closure issues. There is clearly a need to identify which agency or level of government should be accountable and have the responsibility for dealing with mine closure issues. This was clearly identified on the X Brazilian Congress of Geology and Environment held in Ouro Preto on August 2002 where DNPM responsibilities for the mine closure process diverged from those of the Environment State Foundation (FEAM). There is a need for delegation of administrative responsibilities by one level of government to another and/or intergovernmental or interagency coordination of overlapping activities through agreements and memoranda of understanding.

In Brazil, the EIA and the PRAD (required for mines operating before the law enactment in 1989) are the only documents required by the environmental agencies that relate to mine closure. However, even as a statutory prerequisite for the development of a mining project, their role in planning for closure are limited by the fact that in practice they are reactive, static and short-term in design. This is true especially for PRAD that does not take account of the evolutionary nature of mine development and fails to sufficiently integrate environmental considerations into mine planning throughout the project life cycle.

2 – Lack of Qualified Staff

As a result of the Brazilian long-term policy of reducing the public sector's posts, agencies (particularly, DNPM and environmental agencies) lack competent personnel and do not have staff experienced with the nuances of mine closure issues. In addition such institutions lack reasonable level of resources to deal with mine closure.

3 – Lack of Closure Criteria

A challenge facing regulatory agencies and the mining industry is a matter of generic or site-specific completion criteria. Generic completion criteria can assist on achieving consistency throughout the industry but the diversity of mining operations and ecosystems in many countries, states, provinces, regions or even sites demands site-specific criteria. Although some regulatory systems have general criteria in place, as the system applied to coal mining in the US (US Government, 1993; Danielson and Nixon, 1999), the mining industry and governmental agencies endorse the adoption of site-specific criteria. Jarvis (1998) gives a good example of working together, Alcoa and governmental agency as well as public involvement and consultation process, on establishment and implementing site-specific closure criteria.

Criteria for vegetation density and diversity, soil erosion rates and soil profile development, for example, are still not established in Brazil, although PRAD requirement exist since 1989. Such criteria form the basis for assessing success in rehabilitation, but are not, usually, prescribed or quantified. However, some broad guidelines do exist, principally those elaborated by the Brazilian Association of Technical Norms (ABNT) and adopted by environmental agencies. Examples include the ABNT norms for Design and Construction of Tailings Dams (NBR-13028, 1993), Design and Construction of

Waste Dumps (NBR-13029, 1993) and Destruction of Cyanide in Effluents (NBR-13744, 1996).

4 – Lack of Financial Provision and Guarantee

Most countries require a financial guarantee attached to closure plan. This should provide a guarantee that rehabilitation plans will be completed should the proponent fail to do so through premature closing, financial default or other causes. Financial bonds or guarantees are an essential element of the closure plan and licensing process (Miller, 1998; Nazari, 1999). Obviously, financial provisions need to be kept adjusted for changes in the operation or simply for inflation. Given the absence of mine closure programmes, in Brazil, there is no requirement for mining company to make any form of financial provision that guarantees the implementation of the closure plan. In systems that require financial guarantees, the cost of maintaining the guarantee and the advantages of lowering or terminating it are considered strong incentives for companies to begin the closure programme and to continue it in every detail (Anderson, 1999; Danielson and Nixon, 1999).

Steps for Achieving Sustainable Development Succeeding Mine Closure

Following the recommended steps for achieving sustainable development often mine closure are presented.

First, it is necessary to review all legislation that directly or indirectly affects on achieving comprehensive mine closure and provides for sustainable development. This would include either to amend or to put in place additional legislation, the mining law, environmental law, foreign investment, land use law, financial law, water law, forestry law and indigenous people law to ensure comprehensive mine closure and sustainable development. Related to this should be the realisation that there is a growing body of international law in international treaties, conventions, declarations and codes of conduct, which can be used as guidelines to determine the obligations under international law for governments and the multinational industry, as for example, Kyoto Protocol, Basel Convention and Rio 10+.

Second, future Brazilian government mine closure and sustainable development policies must be made to conform to the needs of the community during and after mining. Land use in mining area should provide for alternative land, for comparable use, to replace land lost to mining. Examples of land use conflict in Brazil regarding mining land occur in Mogi das Cruzes in the State of São Paulo with sand and gravel mines and in Vazante, Minas Gerais State with zinc mines. To the extend possible the rehabilitated mining area should allow for the continuation of the traditional economy of the area that developed before and during mining.

Third, a legislative change for Brazil would be the requirement for industry to undertake social-cultural baseline studies, in conjunction with a process of community consultation, to develop a "Social-Cultural Impact Assessment" or "Social Impact Assessment (SCIA or SIA). The SIA would be similar to the EIA, however, should be emphasised that this requirement would not be carried out within a set of defined standards that industry must meet, but through participation in a process by which it is ensure that the concerns of all stakeholders for sustainable development are gathered and integrated into an overall mine project (Clark and Clark, 1996; Warhurst, Macfarlane et al., 1999).

Fourth, the Brazilian government should require a programme of financial guarantees, to ensure all aspects of a mine closure plan are provided for. The importance, nature and use of financial guarantees, in providing for comprehensive mine closure have been discussed in detail by Miller (1991, 1998) and Da Rosa (1999) and can be summarised simply as the use of financial instruments (e.g., certificate of deposit, surety bonds, trust funds, letters of credit, cash) to guarantee that sufficient amount of cash are available to allow the implementation of closure should the proponent fail to do so through premature closing, financial default or other causes.

Fifth, the Brazilian regulatory system should include monitoring and enforcement procedures. Monitoring and inspection are essential since the closure plan is closely linked to the methods of operations and the financial guarantee is dependent upon the plan, departures form the approved operation plan can have drastic impacts both on the feasibility of the closure plan and the cost of its implementation (Sassoon, 1999). In addition, where there is serious non-compliance with the statute, regulations, or permit conditions, the state mine closure agency staff must have the authority to issue an order requiring compliance and file an action in court to enforce the compliance order. Options, after hearing the parts involved, should include suspension or revocation of permits or closure plan approval, orders requiring specific corrective actions, forfeiture of the financial guarantee and imposition of significant financial penalties on the operator (Danielson and Nixon, 1999).

A Proposed Framework for the Brazilian Mine Closure Programme

Following a proposed framework to the Brazilian Mine Closure Programme is presented in Table 9. Exploration (which involves lower levels of impact and is often transitory in nature) and mineral processing are considered part of the broader mining function. While it is acknowledged that the focus of the framework should be primarily on improving closure related activities at operating mines, the principles are relevant to a broad range of activities. This framework, however, does not address the issue of abandoned mines. Historically, mine sites have not been rehabilitated to standards that would be considered acceptable today. While acknowledging the importance of this issue, it was considered more important to address existing mines in an attempt to limit future problems. The proposed framework for a mine closure programme is structured around a set of objectives and principles grouped under five key areas (legislation and completion criteria, planning and management, stakeholder consultation and involvement, financial provision and guarantee, and relinquishment), based on The Australian and New Zealand Minerals and Energy Council (ANZMEC) (ANZMEC, 1999; ANZMEC, 2002). These topics were exhaustively treated in Chapter 3.

Table 9 – Framework on Mine Closure: Summary of Objectives and Principles

Legislation and Completion Criteria

Objective – to establish a clear legislation and a set of environmental indicators, which will demonstrate the successful completion of the closure process.

Principles

1. Legislation should provide a broad regulatory framework for the closure process.
2. It is in the interest of all stakeholders to develop standards that are acceptable to the majority and achievable.
3. An agreed set of environmental indicators is required to demonstrate successful rehabilitation of a mine site.
4. Completion criteria should be specific to the mine being closed and should reflect its unique set of environmental, social and economic circumstances.

Planning and Management

Objectives – to ensure the process of closure occurs in an orderly, cost-effective and timely manner and that there is clear accountability and adequate resources for the implementation of the closure plan.

Principles

1. Mine closure should be integral to the whole of mine life plan.
2. A risk-based approach to planning should reduce both cost and uncertainty.
3. Closure plans should be developed to reflect the status of the project or operation.
4. Conceptual closure planning is required to ensure that closure is technically, economically and socially feasible.
5. The dynamic nature of closure planning requires regular and critical review to reflect changing circumstances.
6. The accountability for resourcing and implementing the closure plan should be clearly identified.
7. Adequate resources must be provided to ensure conformance with the closure plan.
8. The on-going management and monitoring requirements after closure should be assessed and adequately provided for.
9. A closure business plan should include a schedule of actions, responsibilities, resources and timeframes.
10. The implementation of the closure plan should reflect the status of the operation.

Stakeholder Consultation and Involvement

Objective – to ensure that all stakeholders have the opportunity to have their interests considered during the mine closure process.

Principles

1. Identification of stakeholders is an important part of the planning process.
2. Continuous consultation with stakeholders should occur through the life of the mine.
3. Effective consultation is an inclusive process which encompasses all parties.
4. A targeted communication strategy should reflect the needs of the stakeholders groups.
5. Adequate resources should be allocated to ensure the effectiveness of the process.

Table 9 – Framework on Mine Closure: Summary of Objectives and Principles (continuation)

Financial Provision and Guarantee

Objective – to ensure the cost of closure is adequately represented in company accounts and that the community is not left with a liability.

Principles

1. A cost estimate for closure should be developed from the closure plan.
2. Closure costs should be reviewed regularly to reflect changing circumstances
3. The financial provision for closure should reflect the real closure cost.
4. Acceptable accounting standards should be the basis for the financial provision.
5. Adequate securities should protect the community from closure liabilities.
6. Financial guarantee is quite separate from any internal accounting provision and should not in anyway counterbalance this provision.

Relinquishment

Objective – to reach a point where the company has no further responsibility for the site.

Principles

1. A responsible authority should be identified and held accountable to make the final decision on accepting closure.
2. Once the completion criteria have been met, the company may relinquish their tenement without further obligations.

Source (ANZMEC, 2002; Lima and Curi, 2002)

This framework for mine closure is intended to promote a nationally consistent approach to mine closure management in Brazil. Of course, it should not be the purpose of this framework to result in identical legislation in each State. Nevertheless, it should establish principles for mine closure that are agreed between regulating authorities and the mining industry, and which can be applied with greater consistency to the development of regulations by government and mine closure programme by industry.

For the moment a working group formed by members of the Brazilian Mining Institute (IBRAM), environmental agencies, research centres and academics under supervision of the National Department of Mineral Production (DNPM) is investigating all the issues associated with mine closure. Success cases from other countries should be followed, as for example Australia, which culminated in the "ANZMEC Strategic Framework for Mine Closure". Brooks (1997) gives an account of the development process that took place within the Mining Council of Australia (MCA) and the consultation process that accompanied it. An account of the development process and more information is available on the following references (MCA, 1997; ANZMEC, 1999; Biggs, 2000; ANZMEC, 2002).

In Brazil, mine closure is essentially an environmental issue and, therefore, is rarely integrated within the overall concept of sustainable development. In general, the evolution of mine closure policy and legislation lags behind the rapidly changing needs and demands of those individuals most impacted by mine closure. As a result, the role and responsibility of government, industry and stakeholders of all types is rapidly evolving as is the need for governments to develop and implement new policies, legislations and programmes for achieving comprehensive mine closure and post-mining sustainable development. To achieve these objectives Brazilian government should undertake the following:

- Review and revise existing national policies and legislation pertaining to provide for comprehensive mine closure and post-mining sustainable development;
- Launch mine closure and sustainable development policies to conform to the needs of the nation, specifically to the community's needs, such as the provision for a "social safety net" of support, required during and immediately after the transfer of responsibilities from the industry to government. This is clearly important in towns where the main income comes from the mining industry, such as Itabira in Minas Gerais State and many others;
- Closure plans should have associated performance guarantees backed by financial surety instruments;
- Requirements should be legislate for industry to make financial provisions for mine closure and post financial guarantee for closure plan implementation and post-closure monitoring and maintenance activities;
- Requirements should be legislate for industry to perform social impact assessment, similar to existing requirements for EIA.

Although there is no current regulation on mine closure in Brazil, the Brazilian mining industry today is at the forefront of environmental impact minimisation techniques. Numerous case studies provide excellent testament to the industry's rehabilitation expertise, see for example (IBRAM, 1992). However, taking the whole closure process into consideration they are far from excellence, see for example closure problems faced at

Maria Preta Mine (Júnior and Sánches, 2002) and Serra do Navio Mine (Amapá, 2000a; Amapá, 2000b). On the other hand, a success process is expected at Águas Claras Mine (the first big mine to be closed in South America) since its mine closure plan already became a reference in Brazil.

The development and implementation of this framework will imply:

1 – Changes in the Legislation and Regulatory System

Legislation should provide a broad regulatory framework for the closure process. Closure related legislation should be non-prescriptive and objectives based, and should ensure that all reasonable and practicable measures are taken to protect and restore the quality of the environment. It should be clearly understood and accepted that the legislative requirements are the minimum standard required, which best practice should exceed wherever possible. Statutes are often proclaimed in response to bad practice, public outrage or some catastrophic failure. It is in the interest of all parties to avoid the introduction of reactionary and prescriptive legislation that so often follows such events. Future State and Federal legislation should be framed with the following objectives:

- To provide a clear and transparent process;
- To be accessible to, and to protect the interests of, stakeholders through effective consultation;
- To be non-prescriptive and specify objectives to be attained; and
- To have enforceable powers.

Regulation to meet growing community expectations of environmental management is increasing all over the world. Most nations have established nationally, provincially and regionally consistent framework for environmental assessment of new projects and variations to existing projects, based on consultative agreements between the all stakeholders involved. Issues regarding mine closure are an important consideration in the assessment process for mining proposals.

2 – Adoption of Closure Criteria

The question as to what constitutes acceptable closure is often poorly addressed in environmental regulatory statements. The issue of what will happen if rehabilitation does not work is rarely addressed. The lack of completion criteria implies that, even though the rehabilitation programme has ended, the mine company will not be released from its obligations until rehabilitation in the broader sense has been achieved. This lack implies constant demands for further works until complete "rehabilitation" has been achieved. A particular concern for mining companies lies in the frequent requirement that some stated measure has to be met for a number of years. Therefore, efforts are need on the development of some general criteria in order to orientate government agencies and mining companies in preparing a closure. However, it is important to point that criteria for mine closure are site-specific and should be developed in agreement with the stakeholders.

3 – Requirement for Financial Guarantee

Financial guarantee is an effective instrument for enforcing environmental responsibility at closure (Miller, 1998). The imposition of a financial guarantee should not only remove the financial risk to the State of a mining operation, but should also provide an incentive for progressive rehabilitation during the life of the mine. In systems that require financial guarantee, the cost of maintaining the guarantee and the advantages of lowering or terminating it are strong incentives to begin closure programmes and to pursue them diligently. Partial release of the security as work progresses should be seen as a motivation for the company and an equitable reward for the work conducted (Hollands, 1999). Therefore, it is important for mining companies to know that, when the agreed closure criteria are achieved, their financial guarantee can be terminated promptly and that a clear dispute resolution mechanism exists to resolve any disagreement on this subject and release the bond (Hayes, 1994; Danielson and Nixon, 1999).

Financial guarantee, as an economic instrument, must be complemented by permitting, environmental assessment, inspection and enforcement, and education to be effectively implemented (Anderson, 1999). The permitting process is important because it clarifies the criteria for mine closure, impels planning for closure from the outset of mine planning and successfully ensures enforcement of closure criteria. Enforcement and inspections are also essential components of a financial assurance programme. The enforcement capacity of the regulator should be clearly and explicit defined. This allows all parties involved to be aware of the implications for the financial guarantee in case of permit violations or bankruptcy. Inspections require good communication between mining companies and regulators with the goal of identifying faults in the previous closure plan and problems during their formative stages. Early and periodic inspections, in addition help to anticipate problems that may occur only when mining has been completed.

CHAPTER 5 – LIABILITY ASSESSMENT PROGRAMME FOR MINE CLOSURE PLANNING

INTRODUCTION

Environmental concerns and related liability issues often hinder the successful completion of a mine closure and so force remedial action in abandoned mine sites. Historically, the absence of sound environmental operations has resulted in an extensive legacy of environmental and socio-economic implications of mine closure. Residual environmental liabilities are a legacy of the mining industry's past mistakes including mine closure. This stigma has acted as a major impediment that retards a smooth release of rehabilitation bonds, the return of public land to government responsibilities or the transfer of the closed mine site to private or community ownership (Anderson, 1995). At present, the mining industry faces the challenge of controlling both environmental and legal liabilities associated with mine closure.

Closure plans should present five categories of information, namely environmental characterisation; identification and description of operational components including infrastructure and utilities; potential closure issues and liabilities; selection of closure technologies and, finally, schedules and costs. Evaluation of the closure options, then, should be based upon assessment of effectiveness, potential liabilities and costs (Morrey, 1999).

The wide-ranging environmental and socio-economic implications of mine closure require the evaluation of liabilities from technical, environmental, social, financial and regulatory perspectives if they are to be effective. Trends in closure planning involve technical review, assessment and estimation of mine closures liabilities, risk assessment and cost-benefit analysis from both engineering and environmental perspectives. A liability assessment programme is a tool that uses operating as well as compliance records and environmental management procedures to assist the mining industry in planning for mine closure. A liability assessment for mine closure planning is an estimation of the measures necessary to meet closure objectives (Brodie, 1998).

According to Brodie (1998), the practice of an environmental audit provides a useful guide for structuring a liability assessment programme. They have many similarities, except that the scope of a liability assessment is broader including, as it does, all mine closure objectives. The similarities lie in the fact that much of a liability assessment for closure planning purpose focuses on environmental impact control and mitigation. The difference, however, is that liability assessment must consider future changes which may occur at a mine site and provide rehabilitation measures to address long-term concerns.

The focus of this chapter was the development of a new approach to mine closure planning based on audit procedures. This chapter presented a review of environmental audit and outlined the similarities of its objectives with those of a closure plan. These include prevention rather than clean up, identification of possible hazards to the environment and risks to safety, evaluation of environmental consequences, quantification of exposure, setting priorities, quantification of closure bonds and justification of expenditure. Based on these similarities a liability assessment programme for mine closure planning was prepared including the key elements required for an effective audit programme. The objectives and closure measures used as criteria for the liability assessment programme were based on the Rehabilitation of Mines: Guidelines for Proponents developed by the province of Ontario, Canada.

ENVIRONMENTAL AUDIT – BRIEF HISTORY AND DEFINITION

Environmental audits originated in the United States in the 1970s and were adopted widely by the industry in the late 1980s. Originally, it was developed in response to exponential growth in environmental legislation and after a number of companies and managers in their individual capacities had been severely punished for causing environmental damage which led to a consequent increase in liabilities.

Since the 1980s, however, environmental audits have developed as an internal tool to support an environmental management function, which goes much further than mere compliance with legislation. Companies wishing to prove to external parties that the organisation is environmentally trustworthy are also increasingly using environmental audits. It has been applied across the whole range of industrial and commercial activity, from the smallest workshops to the largest industrial plants (mines, refineries, chemical plants) and government service organisations.

A number of bodies such as the International Chamber of Commerce (ICC) and the International Organisation for Standardisation (ISO) have developed detailed definitions for environmental auditing. For its purposes, the International Chamber of Commerce defines an environmental audit as "a management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organisations perform" (ICC, 1986). The aim is to help safeguard the environment by facilitating the control of environmental practices and assessing compliance with company policies.

The International Organisation for Standardisation defines environmental audit as "a systematic, documented verification process of objectively obtaining and evaluating audit evidence to determine whether specific environmental activities, events, conditions and management systems, or matters pertaining to them conform with audit criteria and the results are then communicated to the client" (ISO 14010, 1996; ISO 14011, 1996).

Environmental audit has been defined in many other ways. There include:

- Checking compliance with environmental regulations by single corporations or projects at single sites (Zirschky, 1990; Scaife, 1991; Berger *et al.*, 1992).
- Inventory of off-site emissions and on-site hazardous materials and assessment of risks (Turner and Ruffio, 1993).
- Systematic checking of environmental monitoring data against impact predictions made during environmental impact assessment (Dipper *et al.*, 1998; Wood, 1999; Wood *et al.*, 2000).
- Reviewing and evaluating corporate environmental management programmes, both public and private sector (Brownlow and Zines, 1995; Sinclair-Desgagne and Gabel, 1997).
- Assessing adequacy of corporate management structures used to achieve compliance with environmental legislation (Priznar *et al.*, 1992; Roig, 1995).
- Examining financial and legal risks associated with past, present and future environmental management by other companies involved in mergers and

acquisitions (Middendorf, 1991; Holliday, 1993; Brodie, 1998; Anderson *et al.*, 1999).

The function of an environmental audit is to identify areas of non-compliance and long-term liability, develop actions necessary to return to compliance and establish a timeframe for completion. An audit can be conducted for each environmental programme and cannot only establish on-site, but off-site liabilities as well. It attempts to review, to the detail the audit objective necessitates, the procedures, practices and management plans established for the environmental programmes.

Environmental auditing is now common practice in the larger mining industry operations all over the world (Buckley, 1990; Middendorf, 1991; Scaife, 1991; Danni and Hardaway, 1992; Holliday, 1993; Buckley, 1995; Braga, Filho *et al.*, 1996; EPA, 1996; Eyre and Veranneman, 1999). Although the level of its application varies widely, it is accepted as essential to best practice environmental management in mining for both small and large operations. Recently, due diligence leading to successful acquisition of state owned mining companies in South America has required evaluation of both assets and liabilities (Kaufman and Moreland, 1993). However, liability assessment as a management tool for mine closure planning, the main focus of this thesis, has not previously been reported.

Similar to an environmental audit, a closure plan is a tool of EMS. Proper development of a closure plan is dependent on recognising the principles of environmental auditing. These include prevention rather than clean up, identification of possible hazards to the environment and risks to safety, evaluation of environmental consequences, quantification of exposure, setting priorities, quantification of bonds and justification of expenditure. The following paragraphs focus on how these principles are related to mine closure and the potential use of environmental auditing techniques in operating mines for mine closure planning.

LIABILITY ASSESSMENT PROGRAMME FOR MINE CLOSURE PLANNING

Liability assessment has become a standard tool for property evaluation before a financial transaction and is normally conducted when transfer of property is anticipated between two parties. It is also used for refinancing or before a long-term lease agreement. Liability assessment has been used in the U.S. to establish innocent acquisition during purchase, takeover and merger and that due diligence has been observed in the transfer under the Comprehensive Environmental Response and Liability Act (CERCLA). The financial community have also used it to protect themselves should a loan default result in foreclosure and the associated environmental liabilities of the property which follow (Ruchti and Francois, 1993; Anderson, 1995; Neale and Green, 1996; Anderson *et al.*, 1999).

Frequently, because incidents and situations which result in environmental effects are not identified, there is a need for remediation of the impacts. Carrying out a liability assessment of a mine operation, even if it is qualitative, should enable us to introduce engineering or administrative controls so that the likelihood of the incident occurring is greatly reduced. A liability assessment can also allow mining companies to identify situations where there is some risk to the environment for a mine operation focusing on mine closure issues. For example, an assessment of a tailings dam may identify risks of seepage into groundwater, or failure of the dam which put at risk the community sited downstream of the dam. Contamination of groundwater or safety risk is therefore recognised as risks which need to be managed. By focusing not only on the likelihood of a release or failure, but also on the impacts, mining companies can gain some insight into the environmental consequences of the incident. In addition, this allows decisions to be made on prevention or remediation (Robertson, 1989; Anderson, 1995; White, 1996; Harries, 1997; Brodie, 1998; Gerlach, 1998).

In some cases, particularly where good database of exposure information is available, it may not only be possible to quantify the exposure of sensitive species or humans to substance that may be released or that may remain on the site, but be assessed by these receptors. This will allow mining companies to determine the extent of the environmental or health effects and, therefore, the severity of risk (Kmenta, 1995; Neale and Green, 1996; Harries, 1997; Jones, 1998).

Once the liabilities from a range of situations and mine components are identified, it may be possible to rank these on the basis of exposure or consequences. Therefore, situations with the highest environmental liability can be given priority for action. In many cases, however, this cannot be done as little is known about the real liability of the situation or it is difficult to compare disparate liabilities (Harries, 1997; Jones, 1998). For example, if an assessment of a tailings dam showed that, in five years time, there was a high risk of contamination of groundwater used for stock watering and a high risk of generation of dust which could affect the quality of life in a nearby community, which of these would receive higher priority?

By establishing the overall environmental liability from a mining operation, it may be possible to calculate the required expenditure to minimise the risk to an acceptable level. This level of expenditure can then be used to calculate the rehabilitation bond to be established for the operation. This bond could be reviewed at regular interval and, if actions are taken to reduce the subsequent liability and, therefore, the expenditure required, a reduction may be justified (Anderson, 1995; Harries, 1997; Jones, 1998; Anderson, Orava *et al.*, 1999).

Finally, clear and logical identification of the liabilities can assist a risk assessment and cost-benefit analysis essential in the justification of preventive or remedial actions. Without any presentation of the potential environmental consequences, justification of this expenditure may be difficult.

Environmental liabilities can affect a company's earnings, profitability and long-term competitive position. In terms of mine closure, rehabilitation, maintenance and monitoring are examples of environmental liabilities. Rehabilitation of a mine site can represent a major liability and often requires the continuation of activities long after resource extraction and processing has ceased. Maintenance of environmental quality can represent a significant liability in terms of ongoing costs which may be incurred during the lifetime of a project and also after it has been completed. After the "closure" of a mining project, maintenance requirements may extend for many years, or even, indefinitely, especially where acid mine drainage, radioactive contaminants or other organic and inorganic pollutants are concerned. Once a mining project has been completed, monitoring may be required for many years in order to verify that rehabilitation and maintenance programmes are effective.

Liability assessment for mine closure planning should include the key elements required for an effective audit programme. These determine how the audit should be conducted, from the earliest stages of planning through to conducting the assessment, documentation of the results in a written report and then a commitment to follow-up on audit evidence (Kane, 1991; Danni and Hardaway, 1992; EPA, 1996; ISO 14010, 1996; ISO 14011, 1996; Melemore, 1996). Table 10 summarises these elements. In the following sections the applicability of each of these issues included in Table 10 to liability assessment for mine closure planning is discussed.

Table 10 – Key Elements of an Effective Environmental Audit Programme, After Melemore (1996)

Commitment

- Top management commitment

Auditors

- Proficiency
- Due diligence
- Objectivity and independence

Conducting the Assessment

- Objectives
- Scope
- Criteria
- Procedures
- Planned, organised and supervised on-site/field work
- Documentation
- Reporting

Follow-up

- Follow-up process

Commitment

Commitment by top management to comply with closure requirements, to follow up on assessment findings and to recognise and respect the independence of the audit function is essential for a successful liability assessment programme (Kosko and Causey, 1992; Kornreich, 1995). Without it, even the best organised audit programme with all other key elements executed in exceptional manner, cannot be successful. It is important that full management commitment from the highest levels explicitly supports a purposeful and systematic environmental audit programme in order to involve top and low staff of the company. Environmental auditing needs the strong endorsement and active support of top management which have to clearly communicate all the procedures together with the appropriate incentives. Such commitment must be demonstrated by, for example, personal interest and concern, the adoption of high standards, the allocation of appropriated manpower and resources, and the active follow-up of recommendations.

Auditors

In conducting a liability assessment, auditors must be proficient, exercise due professional care and be objective and independent of the audited entity. Proficiency refers to possessing the knowledge, skills and disciplines to match the objectives and scope of the audit. Auditor should have, through education or professional background, an understanding of the operations to be audited or be able to quickly come to an understanding of the operations at the site (Zirschky, 1990; EPA, 1996; Eyre and Veranneman, 1999). In addition, written and verbal communications, organisation, work planning and analytical skills are necessary qualifications of an auditor. Auditors must execute their task such that another competent auditor given the same audit objectives, scope and circumstances could duplicate the audit results (EPA, 1996). This element implies auditors will perform their role in a conscientious manner which is consistent with audit standards and insures sufficient evidence is collected to support audit results. Auditors must perform their role objectively and independently. Independence provides the foundation for assuring the audit results reflect an impartial assessment. These elements allow the auditor to provide management with an impartial and unbiased judgement of the mine's status. In addition, audited entities will tend to request and welcome future audits (EPA, 1996; Eyre and Veranneman, 1999).

Team members must be impartial in their review of the facility's status. Frequently, the most knowledgeable individual for a given area is the manager or supervisor of the area. If the audit team member is such an individual, negative or deficient areas within his own realm of responsibility must be accurately and impartially reported (EPA, 1996).

Depending upon the size of the facility and the complexity of the operations, an audit team may consist of two to ten people (EPA, 1996). The audit team may consist of in-house specialist, external consultants or a combination of both (EPA, 1996; Eyre and

Veranneman, 1999). Company or internal personnel may be part of the audit team, as long as they can function independently of the entity being audited. Often corporate staff conduct audit, or the team is a combination of corporate professionals and those stationed at other facilities in the organisation. Outside consultants and specialists may serve as audit team members as long as they fully understand the audit purpose and protocols. Consultants may be requested to conduct the audit in its entirety. External personnel, however, may not be well suited to evaluate compliance with company policies and procedures. Outside audit teams or team members should be used if the facility is too small to staff a team, facility personnel are too busy to perform the audit or are not qualified, management prefers an independent or more objective assessment, perceived anonymity by facilities may be compared for management consistency on corporate-wide issues.

Professionals from a variety of disciplines may be effective audit team members. For a mine closure purpose audit team members should include mining engineers, hydrogeologists, environmental engineers, geotechnical engineers, geologists, environmental attorneys and environmental control managers, etc. Frequently an auditor's experience and expertise are more important that his educational background. "An auditor must be able to draw upon knowledge, experience and understanding of the best practice in their field of expertise" (Eyre and Veranneman, 1999). It is imperative that auditors know the federal, state and local regulations they will deal with in the audit. It is highly desirable for audit team members to have a primary and secondary expertise. This allows for more interaction among team members and a more conclusive end product. Also, such an audit team may divide work assignments if necessary.

Objectives

Providing the basis for mining companies to plan for mine closure is the primary purpose of a liability assessment programme. To be brought to a successful completion the programme should have objectives defined and agreed with the mining company from the very beginning (Kornreich, 1995; ISO 14010, 1996; ISO 14011, 1996). Within the context of the mine closure these objectives can be defined as: to identify potential liabilities at the mine site and anticipate closure liabilities; to review and evaluate the adequacy, viability and efficiency of corporate environmental management programmes to achieve the closure objectives; to cost estimate the measures for meeting closure objectives.

Liability Assessment Scope

The principle for defining the overall scope of an audit programme involves identifying subject areas, boundary location, performance criteria, and period of review and geography of sites (Diberto, 1995). The scope of an audit describes its extent and boundaries in terms of location and organisational activities, as well as the efficacy of the environmental management system in place (ISO 14010, 1996; ISO 14011, 1996). The scope of a liability assessment programme for mine closure planning should include all mine closure objectives and be flexible to accommodate the acknowledged concerns of the mining company (Brodie, 1998).

The assessment can be separated into two phases dependent upon the extent of information, database and environmental management quality of the mining company. Phase 1 is non intrusive and determines, qualitatively, the potential liabilities of the mine closure process. Phase 2 is generally required to improve the level of accuracy of the estimates by quantifying mine closure liabilities. Phase 2 should check all activities previously considered during Phase 1, plus sampling, collection, measurement, assessment and characterisation of soils, rocks and water on site if necessary. In addition, measurement of dams and spillways, as well as identification of any meteorological, seismic and erosive events and processes of significance should be recorded. The combined results of Phase 1 and 2 can provide the necessary information for developing a mine closure plan, including timetables and costs. Clearly, the quality of the environmental data and technical reports determine the accuracy of the assessment. Thus, a good initial EIS, in conjunction with updated environmental and social data, and a well-structured environmental management system and monitoring records can eliminate many Phase 2 activities.

Table 11 lists the general protocol of a liability assessment for mine closure purposes. A review of documents and the following interviews with managers and site inspections should cover all items listed in Table 11. The documents to be reviewed should include the EIS; annual company reports; geotechnical, geochemical, biological and water quality technical reports; compliance records; mining plans, mining licences and environmental permits.

Table 11 – General Protocol of the Liability Assessment

History and Operating Plan
- Site history and project schedule
- Mine development rock, ore and concentrate management
- Overburden and waste rock disposal
- Milling process
- Tailings disposal
- Chemicals and fuel storage
- Buildings and infrastructure
- Water management

Current Environmental Conditions of the Site
- Climate and Local Air Quality
- Geology, Mineralogy and Soils
- Topography
- Hydrology and Hydrogeology
- Water and Sediment Quality
- Plant and Animal Life

Environmental Management System
- Environmental Laws and Procedures
- Environmental Policy & Guidelines
- Environmental Personal
- Environmental Budget
- Environmental Training
- Thirty Party Environmental Involvement
- Data Collection and Storage Systems
- Public Relations on Environmental Matters
- Staff Suggestion Schemes

Emergency Response Procedures
- Site Security and Safety
- Documentation of Procedures
- Scope and Detail of Procedures
- Liaison with External Authorities
- Natural Disaster Planning
- Staff Training and Knowledge

Rehabilitation Plan
- Plant, Equipment, Buildings and Infrastructure
- Mine Workings
- Water Management and Treatment
- Tailings and other Water Management Systems
- Disposal of Waste Rock and Solid Waste
- Chemical and Fuel Storage Areas
- Hazardous Waste Storage and Disposal
- Progressive Rehabilitation

Monitoring Programme
- Physical Stability
- Chemical Stability and Water Quality
- Biomonitoring

Criteria for Liability Assessment

The criteria should include any guidelines and best practice on mine closure matters, as well as corporate policy and environmental management system with which evidence collected during the liability assessment can be compared. A brief summary of potential control technologies for chemical stability is showed in Table 12. Tables 13 to 18 list general closure objectives and measures to be considered for each mine component as well as non-compliance with objectives (column 1) and measures (column 2) which must be indicated. These tables were based on published mine closure guidelines and related to open pits, waste dumps, tailings dams, landfills, buildings and equipment and water management facilities respectively (Ontario, 1995). With respect to these components, mine closure objectives and measures should ensure physical, chemical and biological stability, effective land use, secure environmental procedures and emergence measures to be taken in the event of a disaster.

Closure measures for physical stability must address the deterioration of facilities remaining on a mine site after operations cease. Such facilities may be made of soil and rock, or such man-made material as concrete or steel. Therefore, potential structural failures caused by perpetual forces and dynamic events should be assessed. Many of the physical considerations pertaining to closure are the same as those that occur during mining operations. The differences, however, relate to the longer time span for which structures need to remain stable, fixed and immovable. The difference in time scale is likely to be an order of magnitude; a minimum of 200 years for closure, compared to approximately 20 years for operations. Thus, gradual changes in soil and rock conditions, coupled with changing groundwater status may dictate the need for a more conservative choice of design parameters to meet closure criteria.

Pits, tailings dams and waste dump slopes need careful consideration for longevity. Although immediate static conditions may be satisfactory, long-term dynamic forces may suggest the need for extensive protective measures. Since gradual deterioration of materials can take place over time due to both physical and chemical weathering, conservative values of strength parameters should be selected.

Chemical stability issues include acid drainage, leaching of metals and flushing of processing plant reagents or other chemicals. Generally, measures for control of chemical reactions and treatment of drainage must be specific to the source and contaminant type.

Table 12 – Potential Control Technologies for Chemical Stability

Technology	Plant Agents	Acid Drainage	Metal Leaching
Control of Reactions			
Conditioning of waste/removal of deleterious minerals		X	X
Covers and seals for exclusion of water		X	X
Covers and seals for exclusion of oxygen		X	
Blending/base addition		X	
Bactericides (short term only)		X	
Change plant process, change reagents	X		
Change plant process, add neutralising agents	X		
Control of Migration			
Covers and seals to reduce infiltration	X	X	X
Controlled placement to reduce infiltration	X	X	X
Diversion of surface water	X	X	X
Interception of groundwater	X	X	X
Collection and Treatment			
Active treatment in chemical treatment plant	X	X	X
Passive treatment using wetland	X	X	X
Passive treatment using trench			X
Passive treatment using retention pond	X		

Source: Adapted from Ontario (1995)

Table 13 – Closure Objectives and Measures for Open Pit

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Safety	Restrict access to hazardous areas; Emergency access to water.	Ditch and berm; Fence, and sign post, if necessary; Slope stabilisation; Provides access to water.		
Slope Failure	Prevent deep seated failure, if practical; Control sediment release, if necessary.	Restrict access with ditch/berm and, if necessary, fence and sign post; Revegetate or place riprap on slopes; Provide stable spillway and overflow channel.		
Chemical Stability				
Acid drainage and/or leaching of metals	Meet water quality objectives by controlling reactions and/or migration, collect and treat.	Flood control reactions; Cover to control reactions and/or migration; Collect and treat.		
Land Use				
Productivity and visual impact	Return to original or approved use.	Backfill pit; Flatten slopes; Contour-blend with natural topography; Revegetate slopes; Rehabilitate for fish, waterfowl, wildlife habitat.		

Source: Adapted from Ontario (1995)

Table 14 – Closure Objectives and Measures for Water Management

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Water dams	Ensure long-term stability with no overtopping; Prevent erosion.	Monitor/maintain embankment indefinitely or breach; Protect erodible slopes; Plug intake with concrete, plug decants and remove towers; Maintain operating spillway preferably in durable rock.		
Ditches	Adequate flood capacity; Prevent blockage and overtopping.	Design for extreme events; Construct from materials suitable for long-term stability;		
	Prevent erosion	Provide riprap protection; Define and provide for long-term stability.		
Culverts	Ensure maintenance free passage of water under design flood conditions.	Remove culvert and breach, otherwise upgrade for design flood; Provide for long-term maintenance.		
Storage tanks	Remove	Drain, remove or knock down, fill, and cover.		
Pipelines	Remove surface and large shallow pipes.	Remove surface and large shallow pipes, plug pipes at depth.		
Chemical Stability				
Contaminated reservoirs	Meet water quality objectives by controlling reactions and/or migration, collect and treat.	Drain, treat and discharge; or monitor and treat indefinitely; Strip and dispose of contaminated soil in tailings basin or other approved location; Breach dam; Revegetate.		
Land Use				
Dams	Restore drainage patterns.	Breach and restore to erosion resistant.		
	Determine if alternative use exists.	Define means for transfer of ownership.		
Reservoirs	Return to original or approved use.	Maintain lake and transfer ownership, or drain and revegetate.		
Ditches	Restore drainage patterns.	Grade and establish vegetation.		

Source: Adapted from Ontario (1995)

Table 15 – Closure Objectives and Measures for Waste Rock and Overburden Piles

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Slope failure	Avoid deep-seated failure, large surface slumps and sediment release.	Site selection to avoid low strength foundations; Construct in lifts to achieve flatter slopes; Internal drains to prevent water table rise; Covers and/or ditches to control water infiltration; Doze crest if required, or construct toe berm to flatten overall slope; Revegetate or establish riprap.		
Chemical Stability				
Acid drainage and/or leaching of metals	Meet water quality objectives by controlling reactions and/or migration; Collect and treat.	Underwater disposal to control reactions; Pre-treatment-blending of alkali material to mitigate acid drainage; Cover to control reactions and/or migration; Segregation of deleterious materials for controlled disposal or cellular pile construction; Regulate seepage quality to meet mine effluent objectives with covers and/or retention pond prior to release; Collect and treat.		
Land Use				
Productivity and visual impacts	Return to original state or other approved use.	Contour-blend with natural topography; Restore vegetation where practical.		

Source: Adapted from Ontario (1995)

Table 16 – Closure Objectives and Measures for Tailings Impoundment Systems

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Tailings surface	Control dust; Control water erosion.	Establish erosion resistant cover of vegetation, soil, riprap or water.		
Dams	Factor or safety > 1.5 for static conditions with erosion resistant; Overtopping protection.	Appropriate site selection and dam design; Stabilise embankments by constructing toe berm to flatten overall slope; Riprap, vegetation or soil cover to control erosion; Increase freeboard and/or upgrade spillway to prevent erosion by overtopping in extreme events.		
Other	Restrict access; Remove or establish long-term stability of spillway, decant towers and pipes.	Ditch/berm/fence to prevent erosion by motorised vehicles; Remove or plug/backfill structures and decant lines through embankments; Design and construct diversions and spillways for extreme events and long-term stability; Define and provide for long-term monitoring and maintenance; Avoid ongoing operation where possible.		
Chemical Stability				
Tailings and pore water	Meet water quality objectives by controlling reactions and/or migration; collect and treat.	Flood to control reactions; Pre-treatment removal of deleterious material for controlled dispersal elsewhere, or blending with alkali material to mitigate acid drainage; Cover to control acid reactions and/or migration using inert material or bog; Ditch to divert runoff;		
Dams and structures	Meet water quality; Collect and treat.	Do not construct with potential acid drainage or leachable materials; Decontaminate and/or remove acid generation or leaching materials.		
Land Use				
Productivity of land and visual impacts	Return to original or approved use.	Rehabilitate by: flood, contour, cover, revegetate, wetland.		

Source: Adapted from Ontario (1995)

Table 17 – Closure Objectives and Measures for Buildings and Equipment

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Buildings, equipment and storage areas	Control inadvertent access.	Decontaminate if necessary, disassemble and remove all equipment and buildings; Backfill excavations; Remove buried tanks; Restore natural drainage.		
Chemical Stability				
Buildings, equipment and storage areas	Meet water quality criteria.	Contaminated soils assessed on case-by-case basis; Leave in place or excavate and dispose of in approved manner.		
	Dispose of surplus chemical off site.	Chemicals of all types to be recycled, returned to vendor, sold, or disposed of in an approved landfill site.		
Land Use				
Buildings, equipment and storage areas	One for each	Contour; Revegetate; Break and bury concrete; Restore natural drainage.		

Source: Adapted from Ontario (1995)

Table 18 – Closure Objectives and Measures for Landfills and other Wastes

Issues	Objectives (1)	Measures (2)	Non-compliance 1	Non-compliance 2
Physical Stability				
Landfill and waste storage areas	Control erosion.	Provide erosion resistant cover; Stabilise slopes; Upgrade diversion structures for appropriate maximum flood.		
Security	Prevent inadvertent access.	Ditch/fence/berm and signpost where remaining facilities are hazardous.		
Chemical Stability				
Landfill and waste storage areas	Meet water quality objectives by controlling reactions and/or migration; Collect and treat.	Divert runoff with ditches or covers; Relocate to controlled disposal facility.		
Land Use				
Landfill and waste storage areas	Return to original or approved use.	Where possible blend to match topography and revegetate.		

Source: Adapted from Ontario (1995)

Liability Assessment Procedures

Whether or not written, the audit programme should be systematic throughout its planning, onsite and follow-up phases. Procedures may include a summary of the process, roles and responsibilities of those involved with the audit and checklists or guidelines. Explicit top management support and commitment to follow-up on liability assessment findings are essential for an effective programme. Arrangements should be made with the mining company to inform directors and managers of departments about the objective and the scope of the liability assessment. The objective is to guarantee company staff involvement in order to:

- Provide the facilities needed to ensure an effective and efficient assessment process;
- Appoint responsible and competent staff to accompany the audit, to act as guides to the site and to ensure other appropriate requirements;
- Provide access to the facilities, personnel, relevant information and records as requested for assessment; and
- Cooperate with the audit-team to allow the audit objectives to be achieved.

The assessment process should collect evidence through interviews, examination of internal documents and reports as well as site inspections. Table 19 lists some issues which should be considered during the checking of reporters and site inspection of mine components in order to collect evidence on their status. In collecting evidence, due consideration should be given to environmental management and procedures, physical and chemical stabilities and post-mining use of the mine components. These data should then be compared with the established criteria. Nonconformity with these criteria or absence of sound procedures to cope with such evidence should be considered a liability in terms of mine closure. After assessment of each component, the findings should be discussed with unit managers to confirm present and projected liabilities.

Table 19 – General Liability Assessment Issues for Mine Components

Units	Issues
Open pit	Slope and bench stability; groundwater and rainwater management; security and unauthorised access; effects of drainage into and from the pit; reinstatement of haul roads; visual impact; pit filling, etc.
Processing plant	Buildings and foundations; mobile and fixed plant; clean up of workshops, fuel and reagent areas; disposal of scrap and waste materials, etc.
Waste rock/overburden piles	Slope stability; effects of seepage on surface and groundwater; dust generation, visual impact, etc.
Tailings management facilities	Dam stability; changes in tailings geochemistry; effects of seepage past the dam and from the base of the impoundment; surface water management and discharge; dust generation from exposed beaches; access and security, etc.
Water management facilities	Dams and reservoirs, settling pounds, culverts, pipelines, spillways or culverts; disposal of processing plant sludge; surface drainage of the site and discharge of drainage waters, etc.
Landfill/waste disposal facilities	Hazardous waste containment; sewage treatment plant; prevention of groundwater contamination; prevention of illegal dumping etc.
Infrastructure	Power and water supply facilities; access roads; transportation and supply depots, railway spur line, etc.

These are shown as open ended by the use of "etc" to ensure that those conducting the assessment consider the likelihood of other issues arising on a case-by-case basis.

Considerable amounts of information should be provided before site inspections take place. These typically consist of:

- Organisational charts, indicating those responsible for the management of the site or unit;
- Site layout and a brief description of operations;
- Regulatory information;
- Copies of licensing and any notices of violations;
- Listing of applicable legislation and relevant government bodies;
- Agreements with and directives from regulatory bodies;
- Copies of the EIS and Monitoring Reports;

- Chemicals management procedures; and
- Environmental emergence response (Scaife, 1991).

Planned, Organised and Supervised On-Site/Field Work

To increase efficient and consistent accomplishment of the audit objectives, the onsite portion of the audit should be planned, organised and supervised. Planning encompasses the audit leader obtaining a level of knowledge about field site sufficient to allow for securing the appropriate resources, timing, protocols, etc, for the audit. This can be accomplished through a pre-audit site visit, completion of a pre-audit questionnaire and discussions with site personnel. This procedure will allow the team leader to organise the schedule for the audit, assign issues to team members and provide team members pre-audit information. Supervision includes directing the efforts of the team, keeping the team on-track and within the defined audit scope, objectives and time frame.

The site visit should consist of a number of distinct operations. First, a meeting should be held with the manager and senior staff to present the purpose, timing and methodology of the liability assessment, and to confirm the schedule for the site review. Secondly, on site interviews should be held with all appropriate site operatives and junior management. A site inspection should take place together with inspection of records at this time. The guide tables prepared in advance of the site visit, based on Tables 13-18, should be used to ensure that significant issues are not ignored. Non-compliance with objectives (column 1) and measures (column 2) should be indicated. Finally, a summary or brief report should be prepared focusing on conclusions, achievements and issues. This is presented and discussed in a final meeting with the manager or director, often described as a "close out" meeting.

Documentation

The audit programme must assure a process is in place for collecting, analysing, interpreting and documenting sufficient evidence to achieve audit objectives. The process typically includes observations, interviews, records review and recording results in working papers. The programme should also include clearly defined document retention guides consistent with the organisation's retention policy and procedures.

Documentation of the information gathered during the assessment is required to substantiate the conclusions reached about the strengths and weakness of environmental management within the company and procedures to meet closure objectives. Working papers (field notes) should describe the conduct and results of the liability assessment, as well as containing all information needed to support the findings. Generally, working papers include three types of information – a general background to the mine; descriptions of the company environmental management programme; actions taken to complete each step of the assessment. These working papers are necessary to prepare a liability assessment report, which is the key document related to the programme.

Liability Assessment Report

The liability assessment report should provide the management with information on the scope, objectives and results of the assessment, as well as emphasising that the company must initiate the measures needed to cope with the mine closure objectives. The report should also include a discussion of the assessment process, overview of the mining company, an executive summary and a presentation of findings. It may include recommendations for corrective action, but this is subject to the audit programme design and the needs of the company.

Liability Assessment Follow-up

The full benefits of a liability assessment will not be realised if appropriate follow-up procedures are not in place and functioning effectively. The findings and recommendations of the liability assessment must be converted into a mine closure plan complete with a timetable, identification of responsibilities and estimated budgets. Effectively implemented, such a plan would reduce mine closure liabilities and assist companies in meeting closure objectives.

CHAPTER 6 – ANALYSIS OF THE ÁGUAS CLARAS MINE LIABILITY ASSESSMENT PROGRAMME

This research project was designed to develop a new approach to mine closure planning based upon environmental audit procedures. The general methodology described in Chapter 5, however, would remain unproven without some attempts at its practical application, so-called "road-testing". Consequently, a case study was established to test the methodology. The Águas Claras Mine in Minas Gerais State, Brazil is an iron ore open pit mine owned by Minerações Brasileira Reunidas (MBR) which is just reaching the end of its economic life it was the case study. It is scheduled for closure in 2001. Thus in 1998 when fieldwork for this research project was undertaken, it was entering the mine closure planning phase. Consequently, with the cooperation of the company, the methodology developed here was tested on the mine. It was felt that the only way to demonstrate the validity of the suggested approach was a real case study where liability assessment would have to stand the scrutiny of mine closure planning and the meet the actual needs for a mine company.

This chapter presents an analysis of the liability assessment approach adopted at Águas Claras Mine by comparing with the theoretical method presented in Chapter 5. To begin the discussion the reasons for selecting Águas Claras Mine as a case study following by an assessment of the top management commitment are provided.

Águas Claras Mine is in the process of closure. This was the first reason for the selection of this mine as a case study. The most important reason, however, is because Águas Claras Mine is one of the biggest iron ore mine, it belongs to the second iron ore mining company in Brazil and its closure plan is expected by both government and industry to become a benchmark for mine closure activities in Minas Gerais State and Brazil. Other reasons for selecting Águas Claras relate to the importance that the closure of this mine is for the mining industry since its characteristics are quite similar to other iron ore mines, which are reaching the end of their productive life in the region. Other motives include:

- Águas Claras is the first big mine closing in the Iron Quadrangle, in Minas Gerais State, in Brazil and even in South America.

- Like Águas Claras Mine there are many other operating mines in Minas Gerais State that are reaching the end of their productive life and because lack of mine closure regulation do not have a closure plan. This, certainly, will turn Águas Claras Mine closure programme a regional and national reference for other closure programmes.
- The Águas Claras Mine closure process parallels the discussion on mine closure in Brazil. It can be said that the Águas Claras Mine closure process instigated such a discussion for a mine closure legislation and regulation in Brazil in both government and mining industry.

At Águas Claras Mine full commitment by top management to comply with closure requirements, to follow up on assessment findings and to recognise and respect the "independence" of the liability assessment for mine closure planning purpose was achieved. Top management commitment can be expressed through the issuance of a formal statement which commits the organisation to compliance with the auditing programme. MBR's top management explicitly supported the liability assessment programme through personal interest and concern (by participating in the pre-assessment meeting, by allocating appropriate manpower and resources, by providing all documentation and information need, and by actively following-up of recommendations). Although MBR did not issue any statement, its most definitive exhibition of management commitment was achieved through provision the resources necessary to establish and implement the liability assessment programme, and through a meeting with site managers where the programme goals and objectives and how the results will be utilized. It is also important to report that just after MBR's top managers received the proposal for this study, they met with shareholders in Japan, when they were asked about the closure plan for the Águas Claras Mine and the liabilities associated with such closure. In fact this event was crucial to induce such a commitment.

After agreement by MBR to become involved in the liability assessment case study, a preliminary questionnaire was submitted to the company in order to obtain the information needed to establish the objectives and scope of the assessment. This questionnaire is presented in Appendix I.

The liability assessment programme designed for the Águas Claras Mine had to be sufficiently flexible to accommodate changes in emphasis based upon information gathered during the audit and to allow the effective use of resources. Following the key elements of the liability assessment programme developed for Águas Claras Mine are analysed having as basis Chapter 5.

Purpose and Objectives

The purpose of this liability assessment was to assist MBR develop a closure plan for Águas Claras Mine. In order to succeed, the liability assessment had the following objectives:

- To review and evaluate the adequacy of MBR's environmental management programme to achieve the closure objectives;
- To identify potential liabilities at closure of the mine;
- To estimate closure cost.

To achieve these objectives the liability assessment programme follows the path of events recommended by the Institute of Chemical Engineers in their Slide Training Package EO4 – Environmental Auditing (ICE, 1986). The two first objectives were fully achieved by this research. MBR's environmental management programme was evaluated and potential liabilities at closure of the Águas Claras Mine were identified. They were documented in the report sent to the company and are present in Chapter 6. The estimate of closure cost, however, was not achieved by this research mainly because lack of data from the company since the post-mining use of the site was not yet defined, for example. According to MBR's information, the estimate closure cost is about U$14 M.

Liability Assessment Scope and Protocol

The scope of the liability assessment programme was planned at the early stage in consultation with MBR staff and established after agreement with the company, as fully recommended (Thompson and Wilson, 1994; Brownlow and Zines, 1995; Roig, 1995;

Stans, 1995; ISO 14011, 1996). Mine management and staff were kept fully informed in order to guarantee the effectiveness of the liability assessment programme. The scope was established following the programme objectives in order to avoid time-consuming.

Similar to Phase 1 environmental site assessment, the liability programme did not include sampling and analysis of the environmental media. Instead, the programme scope involved review of historical documentation and technical reports, review of regulatory records and on-site visual assessment of the mine components as a means of investigating closure liabilities associated with environmental concerns and mine management practices.

Mining enterprises, generally, are divided into discrete units. The scope of the liability assessment for Águas Claras Mine covered all mining facilities, as well as the environmental management system and operational practices of the mining company. For each unit applicable to Águas Claras Mine, the assessment plan dealt with: those rehabilitation measures already carried out, as well as those anticipated; the final use envisaged for each unit; the long-term environmental and security measures adopted. These were assessed under four different headings: post-mining use, physical stability, chemical stability and biological stability. The Águas Claras Mine facilities assessed were:

- The Pit and the Curral Mountain Range;
- Waste dumps;
- Tailings dams;
- Processing plant;
- Railway spur terminal;
- Water systems, sewer, oil and grease systems and chemical products;
- Buildings and infrastructure.

Industry consistently uses protocols to facilitate systematic audits (see for example, Price Waterhouse LLP, 1995). These protocols present the plan for the auditor to follow in order to gain evidence about an organisation's environmental practice (Buckley, 1990; Brownlow and Zines, 1995; Kornreich, 1995; EPA, 1996; ISO 14010, 1996; ISO 14011, 1996). At Águas Claras Mine the general protocol followed is represented in Table 11.

Informally, with MBR and audit team agreement, great emphasis was placed on visual inspection of the mine components. In addition, a review of the company environmental management, records and reports and interviews with mine managers, regulators were considered a priority. So as not to hamper initiative, no checklists were prepared nor no detailed list of instructions to be adhered to. Instead, tables were elaborated to provide a general guide for assessing each area of investigation. However, it should be noted that a detailed protocol provides a format for assigning specific tasks to individual members of a liability assessment team, for comparing what was accomplished during the assessment with the original liability plan and for summarising and recording the work in progress and work completed. Therefore, the approach used is not recommended where liability assessment team is rotated. In this case such an approach does not ensure consistency with the liability assessment process and reporting procedures.

Audit Criteria for the Águas Claras Mine Liability Assessment Programme

The criteria for an assessment, as described in Chapter 5, were submitted to MBR for its agreement. In addition, details of MBR policy and environmental management system were included so that any evidence collected could be compared with these criteria as well. In this study was verified, the need for a better criteria development. Audit criteria must either already exist, or must be developed. At the Águas Claras the audit criteria developed were taken from a general case of objectives and measures (Ontario, 1995) that must be included in planning for mine components closure. Although most of the criteria used were considered valid for the case study, there is a need for developed site-specific criteria based on current regulatory requirements and guidelines. Unfortunately, this was not possible because the lack of mine closure regulatory requirements and guidelines in Brazil. Therefore, site-specific criteria must be developed in order to avoid on-the-spot personal judgement (an audit in which auditors use this kind of judgment can no longer be called an audit) in topics not covered by criteria.

Dates and Duration of Major Liability Assessment Activities

The major assessment activities were conducted at Águas Claras Mine in July 1998 and lasted nine days. Each aspect of the investigation took one day, but the preliminary arrangements, which included an initial presentation of the liability programme to MBR directors, the organisation of site visits and the collection and verification of documents, required two days. These activities included:

- Initial arrangements;
- The Pit and Curral Mountain Range site inspection;
- Waste dumps sites site inspection;
- Tailings dams sites site inspection;
- Processing plant site inspection;
- Infrastructure and the railway spur line site inspection;
- Water systems, sewer, oil and greases systems and chemical products site inspection;
- Meetings with the environmental manager and the directors of the company to present and discuss the assessment findings.

The liability assessment schedule and agenda were developed and logistics were arranged in consultation with the site and team members.

Identification of Audit-team Members

The author of this study led the liability assessment team with the assistance of two engineers of MBR. Following are described the qualifications of the team:

Team Leader	Bachelor degree in mining engineering, Master of Science degree in mineral processing technology, Ph.D. student in Environmental Management.
MBR member 1	Bachelor degree in geological and civil engineering, Master of Science in geotechnical engineering. Member of the geotechnical staff of MBR.

MBR member 2 Bachelor degree in agronomy engineering. In charge of the rehabilitation programme of MBR.

In conducting a liability assessment, auditors must be proficient, exercise due professional care and be objective and independent of the audited entity. Two members of the team were not independent of the MBR. Actually, they were inside members directly linked with the development of the Águas Claras Mine closure plan. Inside personnel may be included as audit team members as long as the audit team lead is independent of the site (Melemore, 1996). The inclusion of these two members was beneficial since they created the appropriated tone so that the site people became as cooperative as possible. In addition, above all, these members possess the knowledge, skills, disciplines and understanding of the operations at the site to match the objectives and scope of the liability assessment proposed (Zirschky, 1990; EPA, 1996; Eyre and Veranneman, 1999). A potential problem exists when members of the team who are assigned to provide services to the site and earn the confidence of the site personnel are placed in the role of telling all they know in the liability assessment report (this was the case of the two members and they knew where most all of the problems were). Facility staff may perceive this a violation of their trust. However, with the open and committed attitude on the part of top and site managers as well as discretion by the team, this kind of problem was not experienced at Águas Claras Mine.

In the author's point of view, a team combination of internal and external members is crucial for the success of a liability assessment for mine closure planning. While internal members can facilitate the liability assessment by stimulating site people cooperation and better knowing all site operations, an outside member can guarantee an independent and impartial assessment. More outside auditors should be considered when the company lacks qualified in-house personnel to perform audits or time constraints of qualified in-house personnel. However, it should keep in mind that external auditors will not be as familiar with company operations as would inside auditors. The site history, organisational structure and operations will always be more familiar to inside auditors.

Schedule of Meetings Held with Management

The responsibility for making the appointments lay with the two MBR team members. This approach facilitated the meetings as well as reinforced top management commitment. The schedule, however, had to be sufficiently flexible to deal with day-to-day operational constraints at the mine.

Mine Site Interviews

At the opening meetings with the site managers, the purpose, scope, procedures and follow-up process, as well as the expected output generated from the assessment were always reviewed. These meetings were important for sharing any special concerns about the closure process with the team. Most of the onsite aspects of the liability assessment were completed with a closing conference with the site manager to review and discuss the findings identified by the audit team. This was in the form of a verbal review of the assessment. No summary report was presented because of time constraints on the fieldwork.

During site inspection, the auditors used a significant proportion of the time asking questions, engaging in discussion and conducting interviews with facility managers. In this assessment, the interviews were informal in nature. However, an important aspect of the assessment process was to follow some basic steps to obtain the information needed, which involved:

- Planning interview especially setting up the schedule, time and duration, as well as identifying the goal of an interview in advance;
- Ensuring an adequate amount of time to conduct the interview and to explain how the information would be used. Reassuring the interviewee that the purpose of the assessment was to uncover potential liabilities to assist in mine closure planning.
- Requesting a brief overview of the interviewee's job and facility history at the start of the interview;

➢ Writing a summary page just after the end of the interview in order to document it.

Documents Reviewed

Appendix 2 lists most of the documents reviewed during the fieldwork in 1998. They include technical reports, papers, thesis, corporate report, monitoring reports and environmental licences related to the Águas Claras Mine. MBR provided the auditors all documents requested for supporting the liability assessment. In addition, copies of part of these were supplied by the company for preparation of the final report, submitted to the company in 1999, and for the writing up of this thesis. A review of these documents was important to know the history of the mine operations, the activities taken to solve operational problems which affected the environment, as well as to evaluate the implications of company's projects for the mine closure process.

The Águas Claras Mine Liability Assessment Follow-up

Report follow-up is a crucial part of the audit process. Adequate follow-up actions are considered as one of the key factors in a successful liability assessment programme. The liability assessment findings, reported and analysed as prioritised recommendations to MBR, prompted the realization of a need for a quantitative assessment of the main liabilities and risk assessment. This will define the content of the final closure plan for the Águas Claras Mine and the activities to be implemented to achieve an environmentally and socio-economically sound closure.

MBR has contracted a consultancy company (Brandt Engenharia) to conduct the quantitative assessment in accordance with the report of this research. The scope of this study will include the quantification of areas of potential risk, current environmental state of the site as well as the study of potential post-mining uses for the site and a socio-economic assessment of the region under the influence of the Águas Claras Mine.

MBR's long-term development plan provides for increasing ore production from the current 28 to 32 million tonnes per year (Mtpy) by 2004. Most of the Águas Claras Mine employees are being moved to other MBR operations, most of them within a radius of approximately 20 km between the municipalities of Belo Horizonte, Nova Lima and Itabirito. Although the company state that no negative socio-economic impact of Águas Claras Mine closure is expected, since non-unemployment is expected, a socio-economic assessment has also been recommended to MBR to assist the company seek a sustainable post-mining use for the site agreed by all stakeholders.

SUMMARY

Table 11 provided the general protocol to be followed during the assessment and writing up of the liability report to the company. Table 12 was not used in the assessment since Águas Claras Mine, according to pre-questionnaire information, does not have problems with acid mine drainage nor use hazardous chemicals in the ore processing. Tables 13 to 18 were designed based on acceptable closure objectives and applicable measures to environmentally sound close open pits, waste dumps, tailings dams, landfills and disassemble and remove buildings, equipment and water management facilities from a mine site. At Águas Claras Mine, these tables were used as guideline to carry on the liability assessment. As such, these tables were not meticulously followed. This approach was agreed between the auditors to accommodate the specificity of each mine component to be assessed, as well as changes in emphasis based on information gathered.

Tables 13 to 18 and Table 19 proved to be very useful for the preparation of the site visit and discussion with site personnel about closure objectives and measures. Evidence collected during site visit were compared to Tables 13 to 18 to see if closure objectives and measures were in place and if MBR's environmental management could accomplish closure requirements. Nonconformity with the contents of these tables or absence of sound procedures to cope with such evidence was considered a liability in the terms of mine closure. After assessment of each component, the findings were discussed with unit manager to confirm present and projected liabilities. The findings from the case study are presented in Chapter 7. This chapter begins with a review of Águas Claras Mine in the context of MBR and the surrounding area.

CHAPTER 7 – ÁGUAS CLARAS MINE LIABILITY ASSESSMENT PROGRAMME

ÁGUAS CLARAS MINE HISTORY

The Águas Claras Mine in Minas Gerais State is owned by Minerações Brasileiras Reunidas (MBR) of the Companhia Auxiliar de Empresas de Mineração (CAEMI). MBR is Brazil's second largest producer and exporter of iron ore, with gross sales, in 1998, of approximately US$431.9 million and a profit of US$36.9 million. In its operations in the States of Minas Gerais and Rio de Janeiro, MBR provides approximately 2000 direct jobs (MBR, 1998).

Mining operations in the Curral Mountain, where the Águas Claras Mine is located, date from 1904 when an Englishman, George Chalmers, established an iron ore mine there. In 1973, MBR commissioned the Águas Claras Project, mining hematite ore with an average iron content of 68%. Since the beginning of its operation until the liability assessment in 1999, Águas Claras Mine produced about 259 million tons of iron ore with an average iron content of 68% and a stripping ration of 0.6 t/t. The iron ore deposit is composed of high-grade hematite, in both friable and compact forms, and has yielded iron products worldwide recognized by their quality. Before decommissioning is completed, Águas Claras is expected to produce a further 5.5 million tons of iron ore, 2.8 million tons in 2000 and 2.7 million tons in 2001 respectively, amounting to a total of 265 million tons iron ore at the closure.

Figure 5 shows the annual run-of-mine (ROM), the ore processing plant production and the waste rock extraction of Águas Claras Mine since its start up in 1973 until the projected closure in 2001. The mine reached peaks of 15.7 million in 1980 and 14.5 million tons in 1981 for ROM and for the plant respectively. After a decline in production in 1984, the mine increased its production until 1994, reaching a second peak of 13.5 million tons for the plant. Since then, a steady decline in production to an expected 2.7 million tons of product in 2001 reflects the closure process at the Águas Claras Mine.

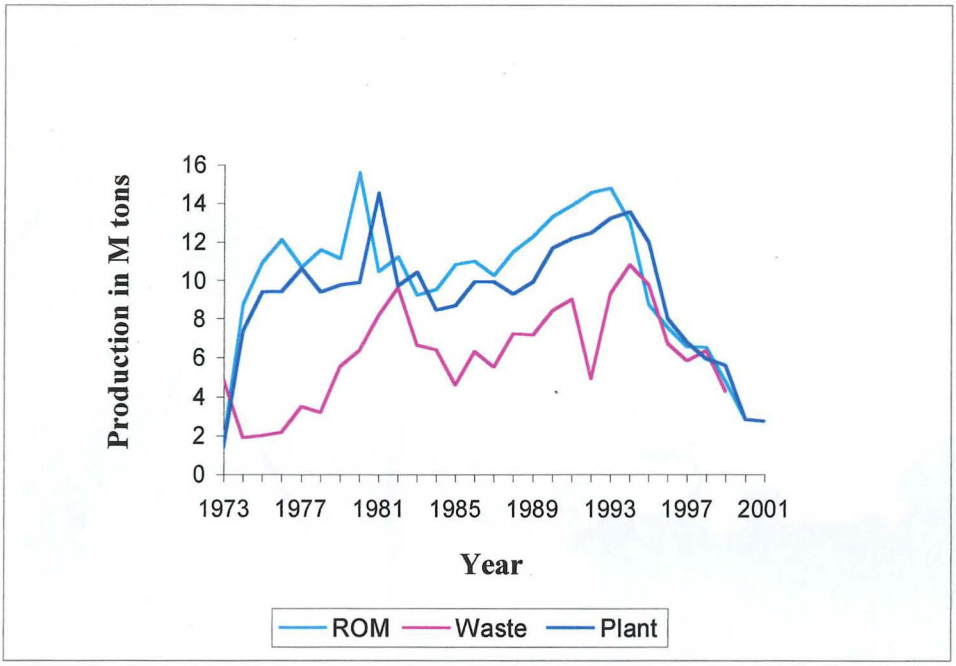

Figure 5 – Águas Claras Mine Production Between 1973 and 2001. Source MBR.

Location of MBR Operations

MBR mining operations are located in an area known as Quadrilátero Ferrífero (Iron Quadrangle) in the central part of Minas Gerais State, South-East Brazil. This area of approximately 7,000 km^2, centred on Latitude 20°15' South, Longitude 43°30' West, is one of the largest iron-ore producing regions in the world. The Iron Quadrangle is a metallogenic province, with reserves of gold, silver, iron ore, manganese and bauxite.

Águas Claras Mine is located in the municipality of Nova Lima in the South range of the Curral Mountain which borders Belo Horizonte city, the capital of Minas Gerais State. Because of its position, the mine is considered an urban operation – it is sited 10 km from the centre of Belo Horizonte. Figure 6 gives the general location of MBR operations in Minas Gerais, 590 km from Guaíba Port in Rio de Janeiro. Figure 7 details MBR operations in the Iron Quadrangle including the main communities and towns under its influence. Plate 1 is an aerial-view of the Águas Claras Mine in which can be seen the proximity to Belo Horizonte City.

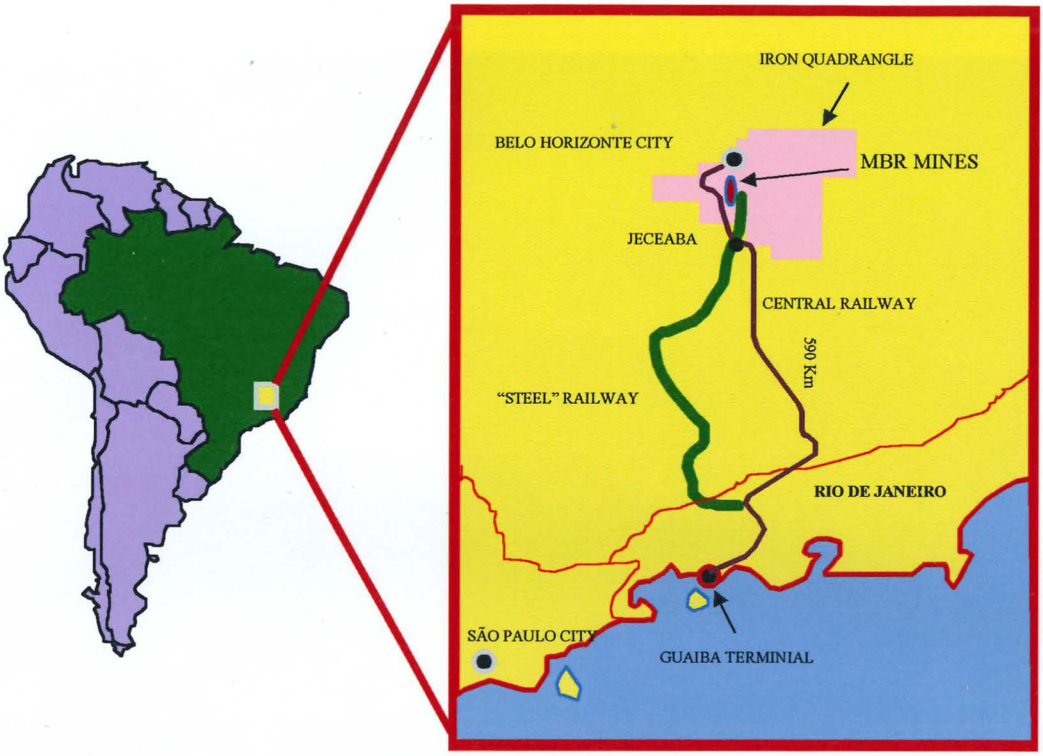

Figure 6 – General Location of MBR Operations in Brazil.

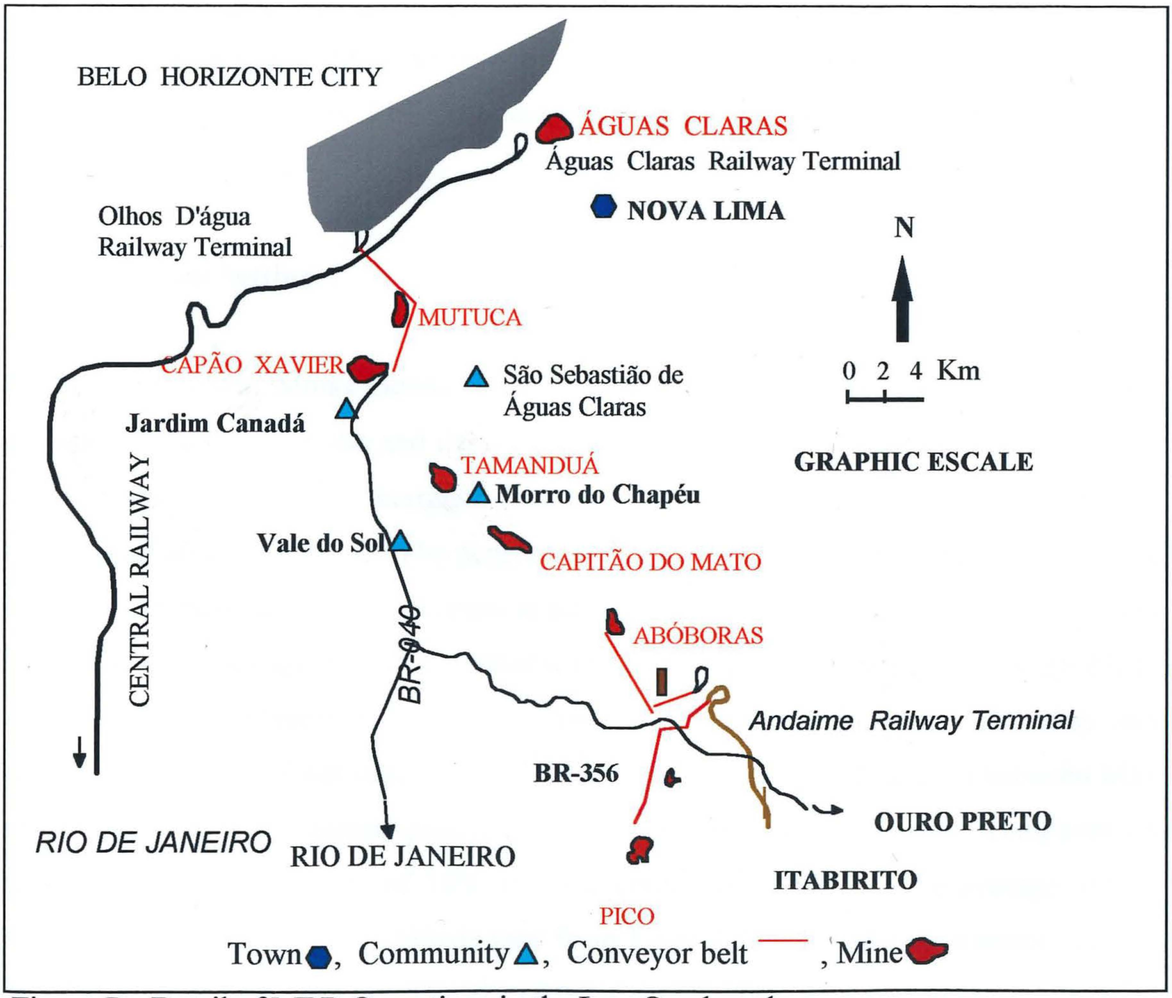

Figure 7 – Detail of MBR Operations in the Iron Quadrangle.

Plate 1 – Águas Claras Mine aerial view showing Belo Horizonte City, the pit, waste dumps Grota 2 and 3, the PFF dike and part of the Jambreiro Forest. (Plate Courtesy MBR)

Environmental Setting

MBR operations in Minas Gerais State lie in the transition zone between the tropical climates of the low latitudes and the temperate climates of the middle latitudes in Brazil. The vegetation consists of "cerrado" (similar to savannah) and forest, with agricultural land and urban developments. The general geomorphology of the area ranges from rolling hills to steep mountains and a variation in elevation from 800 to 1,700 m. Soils in the area have generally poor agricultural potential with poor nutrient content and are susceptible to erosion when vegetation is removed as they lack cohesion. Summers are rainy and winters are dry with a wet season from October to March and a dry season between May and August. Average annual precipitation is approximately 1,880 mm. Temperatures range from an average low of 16°C to an average high of 29°C. The average annual temperature is around 22.5°C. Winds vary from 1.5 to 2.5 m/sec. and the average relative humidity is about 73.1 percent (Brandt, 1999).

There are numerous ephemeral and perennial streams in the area and the surface water quality is generally good. Two streams from Águas Claras Mine are the Águas Claras and the Criminoso, which receive all the effluent from the mine operations. Underground water is present at the mining site with the ore body acting as a confined aquifer. Although almost exclusively limited to the ore body, there has been intense dewatering since 1981 to permit mine operations.

The Águas Claras region supports a wide variety of flora and fauna reflecting the temperate climate. The Jambreiro Forest represents a significant portion of the remaining Atlantic forest and is located in the area of the mining operations. It has been designated a reserve by MBR and occupies an area of about 912 hectares from the total 1,400 ha of Águas Claras Mine. Studies conducted in the Jambreiro Forest have revealed a rich flora with more than 400 different plant species; a fauna of small animals including monkeys, tamandua, capybaras and more than 100 different species of birds (MBR, 1998). The MBR's Environmental Education Centre, managed by a non-governmental organisation in agreement with MBR, is located within the Jambreiro Forest. The Centre develops activities with primary schools from Belo Horizonte and Nova Lima on issues related to environmental preservation and sustainable development.

The urban environment is a strong component of the Águas Claras Mine ecosystem. The Mine is located in the Nova Lima District and adjacent to Belo Horizonte City (Brazilian third largest city), the capital of Minas Gerais State. Belo Horizonte metropolitan area, which includes Nova Lima, has a population of 3,812,675 inhabitants in 1997, which is 22,8% of the population of the whole State (IBGE, 1999a). The socio-economic effects of MBR operations, particularly of the Águas Claras Mine, are clearly apparent in Nova Lima (pop. 59,457 in 1997) where economic prosperity is heavily dependent on revenues from the mining industry.

Geology of the Águas Claras Mine

The Águas Claras Mine is located in the Curral Mountain in the North-west corner of the Iron Quadrangle. Curral Mountain is one of the most prominent topographical features of the region, with maximum elevation of about 1,400 m above sea level. According to Franca (1997), the iron ore deposit is made up of a tabular shaped lens of high-grade iron ore (about 68% iron on average), mainly in the form of friable hematite, with a length of 1,650 m and an average thickness of 250 m. Some lenses of medium hard to hard highly jointed hematite occur in the main iron ore body, usually parallel to the foliation. The hard hematite lenses can reach a thickness of 30 m, occurring more frequently in the NW portion of the mine. The joints are often filled by limonite or manganese. Figure 8 shows the geological section of the Águas Claras Mine.

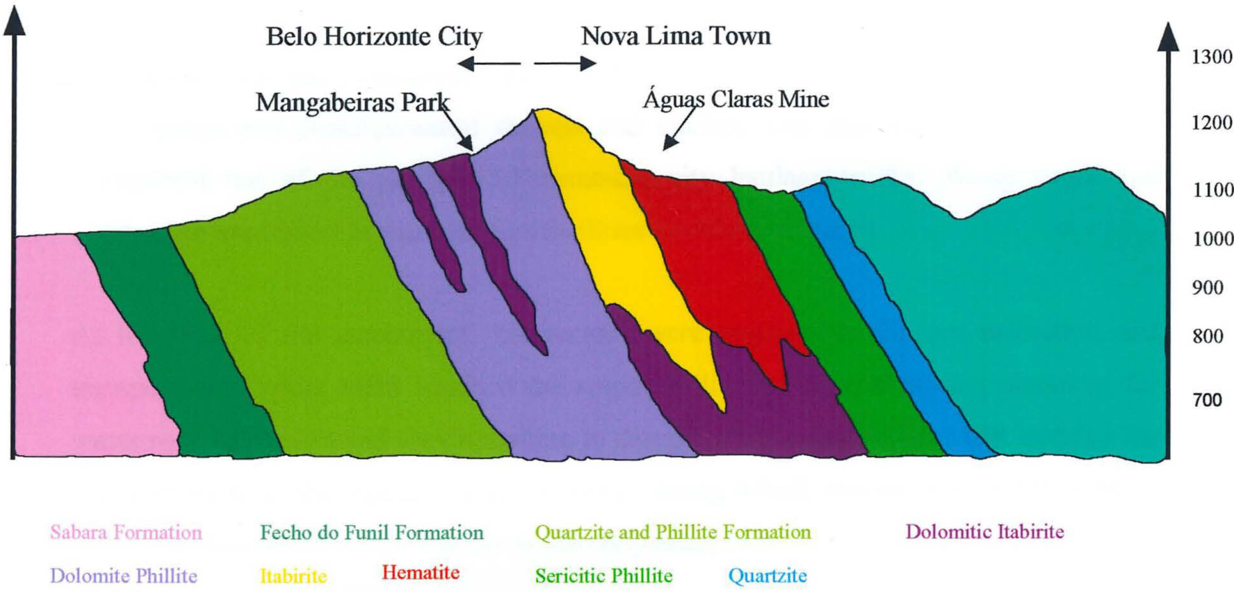

Figure 8 – Águas Claras Mine – Geological Section. Source MBR.

ÁGUAS CLARAS MINE OPERATIONS, COMPONENTS AND FACILITIES

The MBR's production goals and ore commercialisation are the starting point for the overall mining planning of each of the company's mine. Águas Claras annual mining plan is based on the plan of exhaustion of the ore deposit and is, in turn, the basis for a monthly plan. This is designed to address short-term production goals. Both annually and monthly mining plans contain information relating to the following subjects: mine development, projected ore and waste rock production, quantity and quality of the expected products to be transported by railroad, slope stability, drainage projections and dewatering well production estimates, equipment productivity, waste rock and tailings disposal, mine dewatering and areas to be rehabilitated.

Águas Claras Mine is an open-pit mine operated by conventional drill-blast-load-haul methods. Development and operations take into consideration parameters such as slope stability and rock mechanical characteristics, vibration, noise and dewatering systems. Slope stability and rock mechanical characteristics are the principal determinants in the pit development configuration as well the final pit geometry. Geometric characteristics such as overall and inter-bench slope angle, berm width and bench height in the mine varies according to the type of rock being excavated.

Ore, waste rock and overburden have been removed from the open pits by excavation with electric-and diesel-powered shovels and loaders. Ore and waste rock have been transported out of the pit by 150 tonne-capacity haulage trucks. Waste rocks and overburden are placed in waste dumps facilities located near the pit.

At the time of the assessment, contractors were responsible for ore extraction and transportation, while MBR retained the responsibility for general mining planning, for waste rock extraction and for disposition in dumps. This is part of the MBR strategy for decommissioning the Águas Claras facilities, during which mining equipment is being moved to other MBR mines that are in the early stage of production.

Águas Claras ore processing consists of crushing, screening, washing and separating ore products, based on size and metallurgical characteristics. Tailings materials from processing plant at the mine are thickened to recover process water and then conveyed by pipeline to tailings storage facilities.

Ore products are transported from the processing plant by overland conveyer systems to the Águas Claras railway terminal and then loaded onto dedicated trains for transporting to the Guaíba Port. The iron products from Águas Claras Mine are sinter feed fines (SFF), pellet feed fines (PFF) and lump ore (LO). These products are exported to various countries in Asia, Europe, the Middle East and the Americas.

Águas Claras Mine Pit

At closure, the Águas Claras pit will have the following dimensions: 1,200m long, 800m wide and 250m deep. The maximum difference in level from the top of Curral Mountain to the bottom of the pit is 500m. The underground water level was intersected in 1986. During the site assessment, mining operations were 250m below the original water table level. It is expected that, at completion, about 350 million tons of iron ore and about 170 million tons of waste rock will have been extracted from the pit. Slope configurations (angle and height) and the factor of safety for slope (FS > 1.3) have been designed and periodically checked with an emphasis on slope stability. The objective has been to achieve lower levels of slope instability in order to avoid production breakout, personnel accidents and destruction of equipment.

Table 20 gives the pit geometry at Águas Claras Mine. Geometric parameters include the overall slope angle and individual slope angles as well as berm width and bench height for each different face of the pit. The south and east sides are still being mined, therefore, the bench height of about 13m indicates an operation bench. Figure 9 shows the final pit state divided into geomechanical sectors with details of the overall slope angles on each face of the pit. Plate 2 shows a general aerial view of Águas Claras pit from the top of Curral Mountain to the southeast.

Table 20 – Pit Geometry at Águas Claras Mine

Águas Claras Mine's Face	**Geometric Parameters**			
	Overall Angle	**Individual Slope Angle**	**Berm width (m)**	**Benches' Height (m)**
North	37°	43°	7	36 (final)
South above the slope	48°	66°	6	13
South below the slope	44°	60°	6	13
East Itabirite Dolomite	63°	87°	6	13
Northwest below the Patrimônio Peak	37°	43°	7	26 (final)

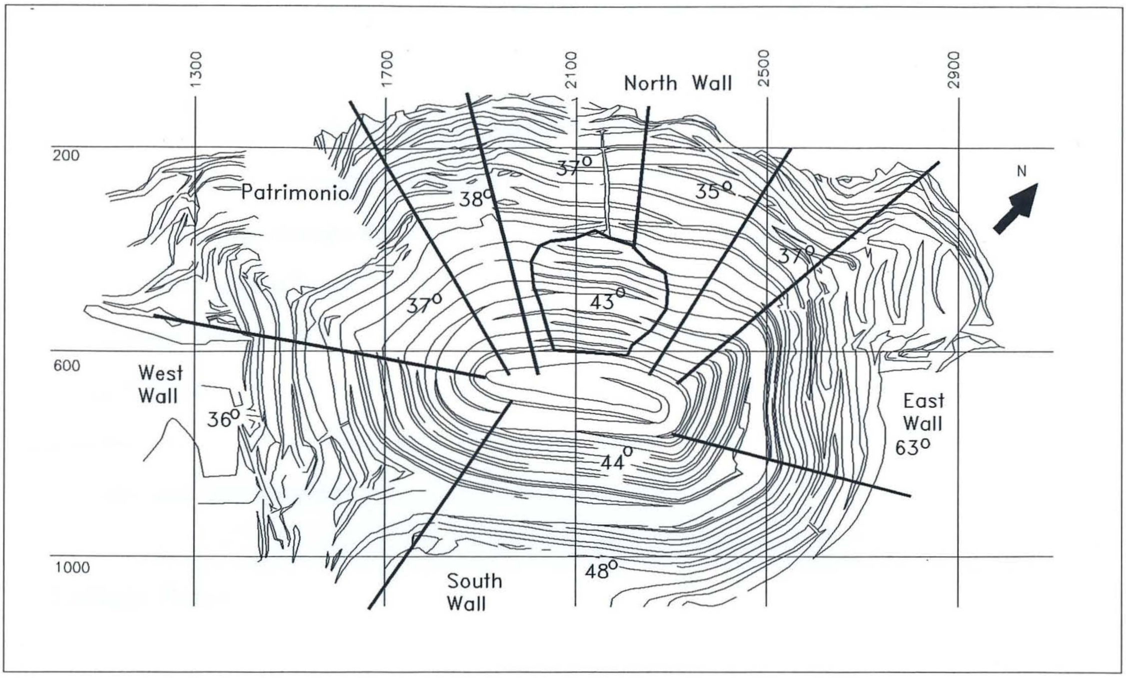

Figure 9 - Geomechanical Sectors of the Águas Claras Pit

Plate 2 – General Aerial View of the Águas Claras Mine Pit from the Top of Curral Mountain. The Curral Mountain ridge, at the bottom, is the boundary of the Belo Horizonte and Nova Lima counties. At top right is Nova Lima town. (Plate courtesy MBR).

Waste Dumps

At Águas Claras Mine there are six waste dumps identified as "Grota" (valley) –2 –1, 0, 1, 2, and 3. Approximately 73 million m^3 of waste were disposed since the beginning of the operation. The dumps have been constructed by disposing of waste in layers 20m high pending final slopes being flattened to 1V: 2H. The dumps have internal drainage systems constructed of hard rock blocks, while surface drainage consists of peripheral channels along the berms. Most of these dumps have a sedimentation pond upstream to receive the internal and external drainage. All waste dumps have instruments to monitor pore pressure and deformation.

Tailings Dams

Apart from iron, tailings from the Águas Claras plant are composed of silica and alumina clay minerals in an average percentage of solids in slurry of 40% and average particle size of 0.01mm. An anionic flocculent (polyacrylamide) used in the thickening process also is present in the tailings.

Águas Claras Mine has two tailings dams. Tailings dam 5 is already filled, while the Grota 3 PFF dam still in operation. Tailings dam 5 has a storage capacity of about 11,300,000m^3, with the Grota 3 PFF dam of the order of 4,200,000m^3.

Tailings dam 5 is located in the valley of the Águas Claras creek. It consists of a 92m high and 400m axis length earth fill wall equipped with a spillway constructed in reinforced concrete with a drainage basin of 14,000,000m^2. The main characteristic of the tailings dam 5 is the arrangement of cross dikes supported on settled tails. These dikes are equipped with a rock lined overflow spillway to allow supernatant water to pass to the lower (downstream) segment of the pond while retaining the settled tail in the upper segment. Two dikes 5m high were constructed to provide for additional tailings storage and, at the same time, to preclude an increase in the level of the settled tails at the location of the reclaim pumps. Reclaimed water from the pond is pumped for reuse in the plant. Plate 3 gives a general view of tailings dam 5. The cross-pond dikes that divide the pond into two sectors are shown at the centre of pond in Plate 3.

The possibility of strain-induced liquefaction of the tails providing foundation support for the dikes and the hazard associated with a potential dike failure limited the construction of a third dike. This imposed a need for another tailing disposal area. An alternative location was the PFF (Pellet Fine Feed) deposit, located above the upper limit of the waste dump "Grota" 3.

Plate 3 – Aerial View of Águas Claras Tailings Dam 5. Cross-pond dikes are in the centre of the Plate. They divide the pond into two segments, the upper one for tails storage and the lower one specially for reclaiming water. (Plate courtesy MBR).

The PFF dike, consisting of "canga" fill, was constructed in the beginning of the Águas Claras Mine operation to provide temporary confinement for PFF ore. However, in February 1993, MBR implemented changes in this dike for tailings storage which included placing low permeability PFF ore on the outside of the dike and over its crest in order to increase the storage capacity of the PFF pond and installing a series of finger drains to provide drainage for the seepage water. Plate 4 shows an aerial view of the PFF dike as well as its position relative to the waste dump Grota 3.

Plate 4 – Aerial View of the PFF Pond. Tailings are pumped from the processing plant to The PFF pond. (Plate courtesy MBR).

Ore Processing Plant

The Águas Claras iron ore processing plant is an old plant with an installed capacity, on a dry-weight basis, of 11 million tons of product per year. The main equipment is involved in crushing, screening, washing and filtering of ore products based on size and the metallurgical characteristics of the ore. Figure 10 shows the general mining and ore processing flowsheet at Águas Claras.

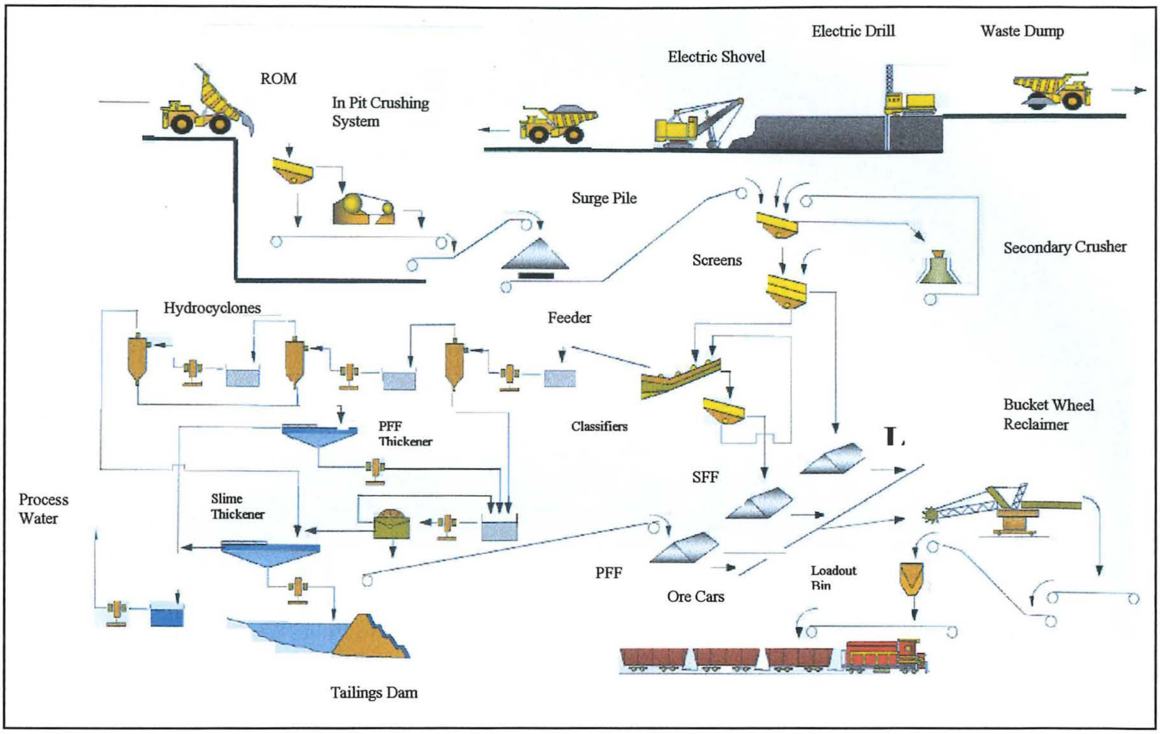

Figure 10 - Águas Claras Mining and Ore Processing General Flowsheet.

Buildings

The main buildings at the Águas Claras Mine house the central offices for MBR. These include support personnel for development, human resources and finance, which serve all mines of MBR. In addition, there are health care facilities, a restaurant, changing rooms, laboratories, and truck scales, repair shops for heavy equipment and light vehicles, truck washeries, fuelling stations and lubricant bays occupying an area of about 14,000m^2. Plate 5 gives a general view of the operational buildings and ore processing plant. All will be demolished at the end of mine operations.

Plate 5 – Aerial View of the Águas Claras Main Facilities. Ore processing plant, heavy equipment garage, restaurant and operational offices can be clearly seen. These facilities will be demolished after the end of the operations and the area rehabilitated. (Plate Courtesy MBR).

The proximity of the Águas Claras Mine with Belo Horizonte makes entire area very attractive for urban development. In a previous study about possible post-mining use, the creation of an estate was proposed by MBR. This estate would occupy the flat areas of the mine as those shown in Plate 5. The pit, given topographical and hydrogelogical conditions, will be turned into a lake. This will be the main feature of the mine site. The state proposal, however, has receiving few priorities by the company since others alternatives uses for the site are being discussed. The development of a convention centre with hotels has received special attention since they imply in maintaining an economic activity for the area with minimal impact on the environment.

ENVIRONMENTAL POLICY AND MANAGEMENT SYSTEM

MBR operations are conducted in accordance with corporate policy as well as with regulations issued by the federal and state authorities. The environmental policy incorporates local, state and national laws and regulations, recognized international guidelines and accepted best management practices throughout the mining industry. Table 21 summarises MBR's environmental policy. As such, MBR accepts responsibility for sound environmental management from exploration to closure of its mining projects.

Table 21 – MBR's Environmental Policy

- Accept environmental management as one of the main priorities of the company being an important factor in sustainable development.
- Evaluate environmental impacts before initiating a new activity or project and during closure of any plant or work site.
- Establish and maintain action plans for significant environmental risk situations.
- Promote internal and external discussion of environmental issues activities related to MBR's activities.
- Minimise adverse environmental impacts in all projects and operations by the use of renewable energy, materials and resources.
- Prepare, train and motivate MBR's employees to conduct tasks in an environmentally responsible manner.
- Adopt legal guidelines and regulations regarding environmental protection in all aspects of operation and demand the same from contractors and suppliers.
- Participate in public and industry initiatives that support or develop programmes and policies of environmental awareness and education.
- Support research that contributes environmental protection technologies.
- Monitor the performance of environmental protection actions and ensure that the Executive is well informed on the matter.

(Source, MBR, 1998)

MBR's Environmental Management System (EMS) is based on established company policy, Brazilian environmental regulations and international protocols. To follow its environmental policy, MBR has formed a management team that is accountable to the

Director of Development. Currently, the team has 26 employees on two supervisory boards – the Rural Areas Board and the Rehabilitation Board. Simultaneously, the environmental management team coordinates the activities of Environmental Follow-up Groups (Portuguese Acronym GAMA). The environmental management team is committed to coordinating and implementing environmental projects as well as facilitating increased environmental awareness at each of the MBR operations. Its functions include:

- Licensing new projects;
- Coordinating with governmental agencies, non-governmental organisations (NGOs), and neighbouring communities;
- Creating environmental education programmes;
- Performing internal audits;
- Developing and enforcing the corporate environmental policy;
- Operating the EMS.

Rural Areas Board is in charge of a supervision of the rural properties. The board is overseen by a supervisor of rural properties (a forestry engineer), a property inspector and ten field personnel. This board is in charge of the following activities:

- Obtaining deforestation permits for current mining operations;
- Providing security for mine operations;
- Preventing forest fires;
- Establishing private national preservation areas (Portuguese acronym RPPNs);
- Conducting internal environmental auditing.

The Environmental Rehabilitation board is overseen by a supervisor for environmental rehabilitation (an agronomy engineer), an agricultural technician, a chemical technician, an environmental sanitation technician and seven field assistants. Their responsibilities include:

- Monitoring water, air and noise parameters;
- Implementing revegetation;
- Conducting internal environmental audits.

The Environmental Follow-up Groups (GAMA) are responsible for monitoring the performance of each operational unit's environmental programmes. GAMAs maintain environmental compliance through regular inspections, internal auditing and suggestions for improving existing environmental programmes. Each GAMA group includes representatives from different departments, who are chosen annually by the superintendent of the operation. The basic activities of GAMA include:

- Bi-monthly monitoring of existing environmental programmes;
- Regular facilities inspections;
- Proposing corrective and preventive measures;
- Maintaining compliance with regards to environmental and health and safety issues;
- Promoting environmental awareness programmes in order to educate personnel on the need for environmental protection.

The environmental management team also runs an annual rainy season action plan, which consists of a site inspection to identify critical areas and those at risk when threatened by continued rainwater during the rainy season. Areas are classified in terms of priority, according to the possible magnitude of the impact if no measures have been taken prior to the rainy season.

Rehabilitation Programme

MBR performs progressive rehabilitation at all of its mine operations with the objective of reducing erosion, physically stabilising areas of disturbance, improving the aesthetic appeal of the impacted areas and reducing closure liabilities. At Águas Claras Mine rehabilitation activities include, apart from the decision of the final use of the site, the selection of remediation measures and further a plan of rehabilitation. The measures commonly adopted are:

- Revegetation by seeding and planting on pit slopes above the proposed lake level.
- Flattening, grading, seeding and planting on all slopes of waste rock dumps.
- Monitoring revegetation success on pit slopes, waste rock dumps and tailings dams.

- Maintenance of uncovered diversion berms to allow vehicular access during revegetation monitoring programme.
- Implementation and maintenance of drainage systems on the upper berms and slopes of the pit.

Monitoring

A comprehensive monitoring programme has been adopted by MBR at Águas Claras Mine. The programme is designed to provide information for the periodic review and any necessary alteration to the management plan to ensure environmental protection. The main objectives are to assess the performance of the actions taken, as well as to demonstrate compliance with regulatory requirements. It includes monitoring the stability of slopes, the quality of the air and of surface and groundwater, as well as noise levels, vibration control and rehabilitation success.

Prisms have been installed on the walls of the pit area, along the railway loop, on the waste dumps and the tailings dams to record position and detect ground movement. These are monitored monthly through a total station system to provide information on the stability of the slopes. High-volume monitors installed at several points around the industrial and pit areas are used to check air quality on a monthly basis. The monitoring points for water quality are also checked monthly. Two main points for water quality monitoring are located on the Águas Claras stream, downstream of Tailings Dam 5, and on the Criminoso stream downstream of Dam 4. Surface water samples are analysed for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oils and greases, Total Suspended Solids (TSS), electrical conductivity, ambient temperature, soluble iron, sediment solids, dissolved oxygen, soluble manganese, water temperature, pH, turbidity, colour and odour. Noise and vibration are monitored as necessary, for example, vibration is always measured when blasting is carried out near Curral Mountain.

During the time of the site visit, in June 1999, a monitoring programme was being conducted to evaluate the overall revegetation success, as rehabilitated areas may require additional maintenance following the first growing season. This monitoring activity is conducted annually before the raining season starts and includes reseeding areas were initial vegetation establishment has been poor, the maintenance of fences and weed and fire control.

DESCRIPTION AND ANALYSIS OF FINDINGS

On site visit, interviews and a review of reports showed that geotechnical problems are the main concern during mining operations, as well as at mine closure. In addition, rehabilitation difficulties and security problems in deterring trespassers are present in most of the Águas Claras Mine components.

The Mine Pit

The Águas Claras Mine pit is the main feature of the area. At closure, the pit will be 1,200m long, 800m wide and 250m deep. The maximum difference in level from the top of Curral Mountain to the bottom of the pit will be approximately 500m. Flooding is the closure option for the pit. A lake will be created by stopping the dewatering system, directing surface drainage to the pit or alternatively, pumping external water to accelerate the pit filling process. The later is a very expensive measure. The lake will have a depth of approximately 239m from an altitude of 866m to 1105m above sea level. Potential liabilities associate with the pit include slope instability in the Patrimônio Peak (northwest sector) and in the southeast sector, the quality of the water in the lake and the security of the area in deterring trespassers. The close proximity of houses from the northwest sector of the pit – a mere 500m – heightens the problem. A risk assessment of waves that can be generated because slope failure into the pit lake is recommended.

The principal concern of the Águas Claras Mine geotechnical group with respect to the pit slopes is related to the south sector and, especially, to the northwest wall at the Patrimônio Peak where a major slope failure occurred in 1992. This extended over a slope height of approximately 240m, from the crest (1340m elevation) to the operational toe (1100m elevation) – a total displacement of about 2 millions tons of ore. The dislocated material ran 500m to the opposite wall, covering the pit floor with debris, burying the in-pit crusher and damaging two trucks. The scars remain and, after geotechnical studies and consultancy reports, MBR have resolved to maintain the failure form as a final wall. The construction of berms and benches along the failure wall is technically feasible, but is prohibited because it requires earthworks in a conservation area. Technical solutions to improve the aesthetics of the wall are recommended. These include revegetation by hydroseeding and placing steel netting to contain rock displacements.

The south wall of the pit also demands special care. This sector is the mine hanging wall and comprises a sequence from bottom to top of dolomitic and sericitic phyllites and quartzite. These rocks vary in consistency from very weak to strong, classes RO to R4 according to the International Society for Rock Mechanics classification (Hoek and Bray, 1977). The quartzite is an aquifer of importance to slope stability. Toppling failures were observed in that sector during site inspection indicating potential instability during lake filling, and observation which accords with the studies of Franca (1998b). Efforts should be made to estimate the need for continued pumping of the quartzite, as well as implementing a monitoring system for these slopes during lake filling.

Rehabilitation activities in the pit involve mainly revegetation and improving surface drainage on the steep slopes. The revegetation process presents several difficulties due to the poor quality of the soil, steep slopes, erosion potential and the fact that the use of equipment is not generally feasible. Plate 6 shows how steep slopes have been successfully revegetated on the north wall of the pit. Several methods for revegetation were applied including hand seeding or hydro-seeding and fixing the grass turfs by using stakes or metallic nets. The need to use metallic nets was dictated simply by the difficult, steep slope characteristics. In addition, deep rooting species have been introduced to improve slope stability.

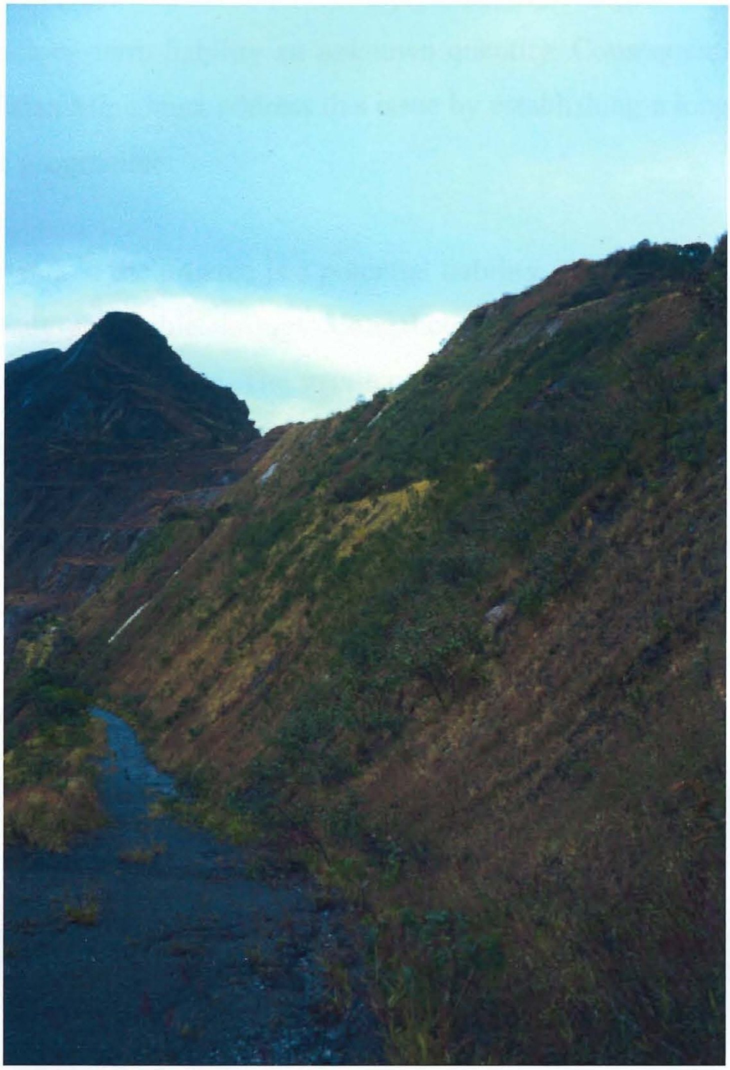

Plate 6 – Steep Slopes Revegetation Process on the North Wall of the Águas Claras Pit.

An illustration of the lake to be created in the void and its position in relation to the Curral Mountain is shown in Plate 7. It is the mineralogical characteristics of the surrounding rocks of the pit walls that will influence the quality of the water in the lake. The most frequently used technique for lake reclamation consists of adding iron compounds, mainly hydroxides to precipitate and retain phosphorus in the sediments. The high iron content at Águas Claras Mine greatly assists this process. According to the report by Sperling (1995), however, deep lakes are rare in Brazil and very little is known about the water quality at such depths in tropical latitudes. The most obvious liability is the possibility of poor or even minimal circulation within the water mass of the lake. It is essential to monitor this and a system should be established for doing so. If after lake formation, the monitoring reveals inadequate circulation, a mechanism for the removal of deep water will have to be constructed (i.e. a pipeline). The implications of this are wide and the potential long-term liability an unknown quantity. Consequently, a closure plan for the Águas Claras Mine must address this issue by establishing a long-term monitoring and maintenance programme.

The risk of accidents in the pit area is a potential liability. The north and northwest faces of the pit are easily accessible through Mangabeiras Municipal Park at Belo Horizonte and by many trails from the city. The maximum altitude from the top of the Patrimônio Peak to the bottom of the pit is 500m and the benches in these faces are 32m high. The risk of people falling in these areas is high. Therefore, a potential liability exists, especially considering the easy access to the locale and its attractiveness for sports such as mountain biking and walking. Consequently, fences and signposts must be erected to restrict access to the pit and an education campaign warning of the risks involved in entering the area should be mounted.

Plate 7 – Planned Final Configuration of the Pit's Lake. The easy access to the lake through Mangabeiras Park, the altitude and the steep slopes make the locale a potential risk for people. (Plate Courtesy MBR).

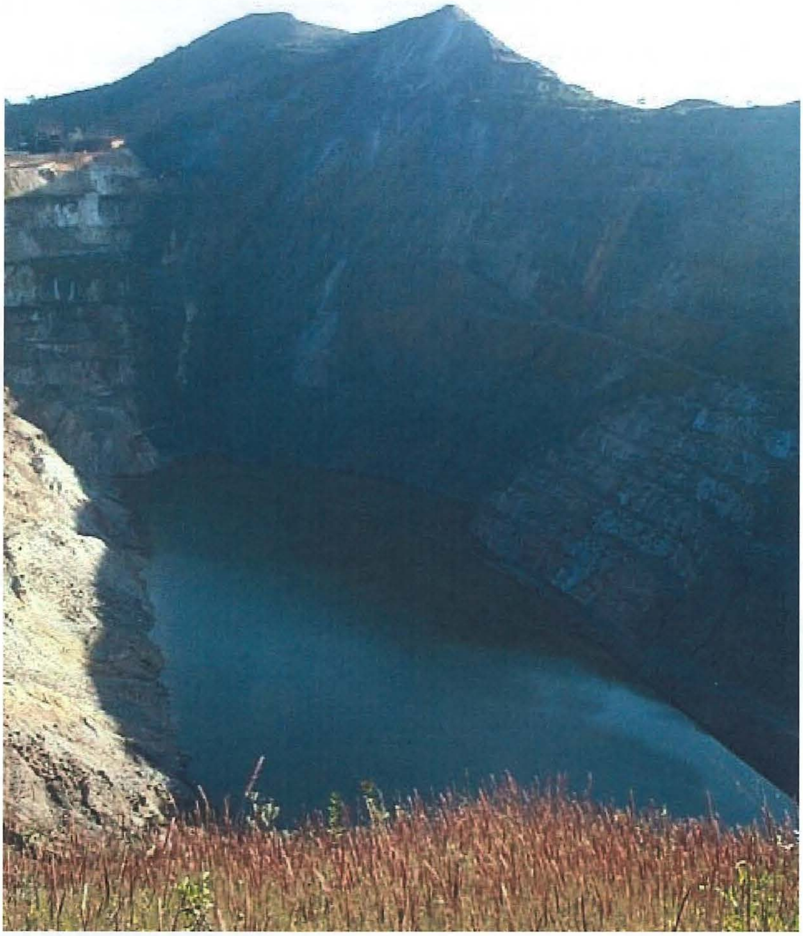

Plate 8 – Pit Lake Partially filled – Picture taken in March 2002. (Plate Courtesy MBR).

Waste Dumps

Each of the six waste dumps of the Águas Claras Mine was inspected to assess potential liabilities and the measures needed to achieve closure objectives. At the time of the site visit for the liability assessment, the waste dumps Grotas –1, 0 and 3 had already been constructed and satisfactorily rehabilitated. Most of the Águas Claras wastes dumps have been created as platforms on the sloped terrain and no signs of physical instability were observed. Assessment of the current situation of each dump has also taken into considerations the monitoring records. Waste rock from Águas Claras Mine consists mainly of quartzite, basic intrusive rocks, phyllites and dolomitic phyllites, so they do not produce acid drainage nor do they have high metal leachability potential.

Rehabilitation measures in the waste dumps include flattening, grading, seeding and planting on all final slopes followed by implementation and maintenance of surface drainage systems on the upper berms and slopes. The state the surface of these dumps varies from well-vegetated slopes to just-revegetated according to the age of the dump. Plates 9 and 10 show the rehabilitation process for the waste dumps. Plate 9, taken during the site visit in June 1999, shows the top of Grota –1 dump under construction and Plate 10, sent six months later by MBR, shows waste dump construction complete and the development of the initial vegetation cover after.

Two dams were constructed to precipitate solids from the Grotas drainage, one for Grota –2; the second for Grota – 3 also receives drainage from the PFF dike. Drainage from the other waste dumps is directed to Tailings Dam 5. These two sedimentation ponds are expected to remain as lakes when the mine ceases operations. Potential liabilities for these facilities are the degradation of water quality and dam structures, as well as security of the site. Attention should be paid to dam #8B regarding overtopping risk. Therefore, its spillway will have to be modified.

The consequence of mine closure for these components is that they will be subject to degradation by human activities. Indeed, Plate 11, taken during site inspection, shows that this degradation has already started. Bottles and other rubbish in the lake illustrate the type of problem that already has been encountered. People from nearby communities frequently use the ponds for camping, swimming and fishing activities. These problems have been minimised by the intense security that has occurred on the site during the time that the mine has been in operation. Security measures, therefore, should be included in the closure plan to avoid such liabilities.

Plate 9 – Top of the Waste Dump, Grota –1, under Construction at the Rim of the Pit.

Plate 10 – View of the Waste Dump, Grota –1, Six Months after the Site Visit. (Plate Courtesy MBR).

Plate 11 - Bottles and Other Rubbish Thrown into the Lake at the Sedimentation Pond.

Tailings Dams

The main concern of the Águas Claras Mine staff was the physical stability of these structures. To collect evidence on this and other issues a visual inspection of all the dams, underdrains, ditches and spillways was made, technical reports were consulted and conceptual and construction details of the tailings dams were examined. There was no sign of gully erosion at the dam or at the water discharge point. There was no evidence of wind erosion, seepage stains or piping, bulging of slopes, sloughing of the crest on either dams or sediment ponds, vegetation growth or debris accumulating and blocking in the ditches and spillways – nothing untoward was detected. The concrete structure of the Tailings Dam 5 spillway, however, needed to be repaired in a few parts to avoid long-term liability. These field observations confirmed the information gathered during interviews with MBR staff that the structures were in a stable condition.

Jambreiro Forest borders Tailings Dam 5. Therefore, special attention need to be given to precautions against forest fires. Especially being close to an inhabited area, these must be expected to occur quite frequently. Fires do not, in themselves, pose a significant threat to the stability of the Dam 5. The loss of vegetation cover, however, may lead to accelerate erosion by wind and water, or the development of oxygen or water pathways along root holes through soil covers. Plate 12 gives a general view of Tailings Dam 5, the red rectangle showing a forest area that was affected by fire a few days before the site visit made in June 1999. Such fires are relatively frequent in the area because of the unauthorised access of people for walking, camping, fishing and hunting.

Plate 12 – General View of the Tailings Dam 5. The area inside the red rectangle shows the after effects of the fire that occurred in June 1999.

According to information gathered from staff interview, the most appropriate final scenario to Tailings Dam 5, would be a lake downstream of the cross-pond dikes followed by a revegetated beach upstream of the dikes. The necessary revegetation process does not appear to be a difficult task, given MBR rehabilitation's experience and the fact that Jambreiro forest surrounds the area, which facilitates the invasion of native plants. A closure plan for the Tailings Dam 5 should address the establishment of appropriate drainage on the site. The plan should ensure that all the water from the drainage basin flows along the rock lined overflow spillway from the dikes. This would avoid erosion of the settlement tailings and guarantee the success of the revegetation.

The long-term disruptive nature of the continuous actions of erosion, physical weathering and biotic activity on the dams is a potential risk (Robertson, 1989). These forces, in combination, may frustrate the company's attempts to achieve long-term stability of the tailings dam. Without maintenance and care, physical failures are inevitable.

The PFF pond will be completely drained at the end of the operation of the ore processing plant. This will considerably reduce the forces acting against the stability of the dike. The geotechnical characteristics of the tailings, such as size distribution (96% to 98% lower than 0.075mm), density *in situ* ($2.9 t/m^3$) and permeability (1.4×10^{-4} cm/sec) would act favourably to settle the sediments in the drained pond. As a security measure, however, given the risk of development of water pore pressure, the erection of any kind of building should be avoided in the area to minimise future liabilities.

Long-term Stability Concerns for Waste Dumps and Tailings Dams

Current design and construction technology are able to achieve stable structures over periods of at least 100 to 200 years. Such waste dumps and tailings dam structures, however, cannot be expected to last for all time. Therefore, their "failure" or degradation is not *a priori* unacceptable. The knowledge of how these degrade, over what time and the consequential rate of release of wastes, however, can help to extend their stability to an appropriate period extending to between 1000 and 2000 years into the future (Robertson and Clifton, 1987; Robertson, 1989). Therefore, the objectives for waste dumps and tailings dams closure planning must include considerations not only of environmental protection, aesthetics and post-mining use, but also of the action of disruptive forces.

These structures are subject to two classes of disruptive forces – short duration extreme events such as flood, fires and earthquakes, which apply forces to the structure in excess of values for which they were originally designed and the slow, but perpetual, action forces which bring about deterioration, such as water and wind erosion, intrusion by roots, animals and man.

Water erosion is probably the single most severe cause of mine waste instability. It can take the form of flood erosion of the diversion works, or sheet and gully erosion of the impoundment surface and embankment slopes. A substantial portion of total erosion occurs during extreme precipitation and floods events. At the Águas Claras Mine, an examination of the projects of Tailings Dam 5, PFF Dike and sedimentation ponds demonstrated that they have been designed and constructed to accommodate the Probable Maximum Flood (PMF). The same was verified for their respective diversion structures constructed with ample width and size to allow for partial blockage or sedimentation. Diversion works are extremely vulnerable to long-term instability, because flood flows generally exceed the values currently in common use for design. Therefore, is recommended that closure diversion works are designed to accommodate the PMF. Sedimentation accumulation in diversion structures is also anticipated at the Águas Claras Mine. Thus, closure plan for these facilities must include a long-term care and maintenance programme.

The Iron Quadrangle region is one of the highest in Brazil and, because of an average annual precipitation of approximately 1,880mm, is highly subject to intermittent erosive forces. The slow but perpetual water erosion process, therefore, should be a major long-term concern for both waste dumps and tailings impoundments at the Águas Claras Mine. Tailings and bare soil would result in excessive sheet and rill erosion, unless the soil contains a high percentage of coarse gravel. Discontinuous cover or periodic cover loss will result in unacceptable erosion rates. Therefore, good grass cover can do much to control this type of erosion, which will become insignificant with continuous forest cover. Rock waste is also effective in controlling erosion of these areas. Gully erosion is a major concern for the long-term stability of tailings dams. Current technology is inadequate to demonstrate the stabilising effect of forest cover. Riprap is the only proven demonstrable control measure for long-term gully erosion prevention. Dams constructed from coarse rock waste or with a layer of heavy riprap would be stable against long-term gully erosion (Caldwell and Robertson, 1986; Robertson and Clifton, 1987; Robertson and Skermer, 1988; Robertson, 1989).

Whilst it is desirable to avoid the need for long-term care and maintenance after closure, it is questionable whether such an objective is technically or economically feasible. Current understanding of long-term effects on stability is limited, as is the ability to design and construct for long-term resistance to both extreme events and perpetual effects. In the absence of maintenance, the risk of failure increases with time. In geological time, “failure” is a certainty. With maintenance, the resistance of a dam to failure can be maintained at a constant level. A more appropriate objective, therefore, is to achieve a condition at closure, for which the risk of failure and required level of maintenance is at an acceptably low level.

A structural and hydraulic risks assessment should be considered. For hydraulic risks it should be considered overtopping, which can occur in the event of insufficient spillway capacity for the maximum probable flood. Two possibilities should be analysed. One is if the dam is going to be preserved with its water body under frequent monitoring. The other is if the dam is going to be decommissioned with no further control. Structural risks regards to the integrity of the dam. A methodology of analysis adopted by the USBR should be considered to assess these risks, which is based upon the performance of the dam, attested by monitoring results and field inspections.

The Águas Claras Ore Processing Plant

The processing plant is old and, after transfer of the equipment to other MBR units or sale for recycling scrap, therefore, the entire structure will be demolished. There is no risk of contamination of the site, because the ore processing technology used does not employs hazardous chemicals. A closure plan for the plant should include, after demolishment of the structures, removing or burring of foundations and the site regrading to avoid long-term liabilities on the site. Plate 13 is a view of the ore processing plant.

Plate 13 – View of the Águas Claras Ore Processing Plant. (Plate Courtesy MBR).

Infrastructure of the Águas Claras Mine

All accesses and roads, regardless of its use, were inspected. In general, the roads were built without specific designs; excepting the mine haul roads and main accesses. Their conditions are usually excellent, with minor and localized problems, in most of the cases with respect to poor drainage maintenance.

One of the main roads within the mine, named "Transgotônica", links the MBR central office to a subsidiary office near the operational site. Several cracks were observed in this structure during site inspection of the surface and downstream slope. These cracks are present at a point where the road was constructed over waste rock dumped during the commissioning of the mine and are a result of superficial movement from waste layer bedding. According to the MBR geotechnical team, these cracks do not require special attention regarding stability of the waste dump. Although the downstream slope is covered with rocks, erosion is evident in this area and its long-term effects can create unstable conditions. Measures to avoid this long-term risk and the aesthetic appeal of the area (Plate 14) must include the closure of the road, its regrading and revegetation.

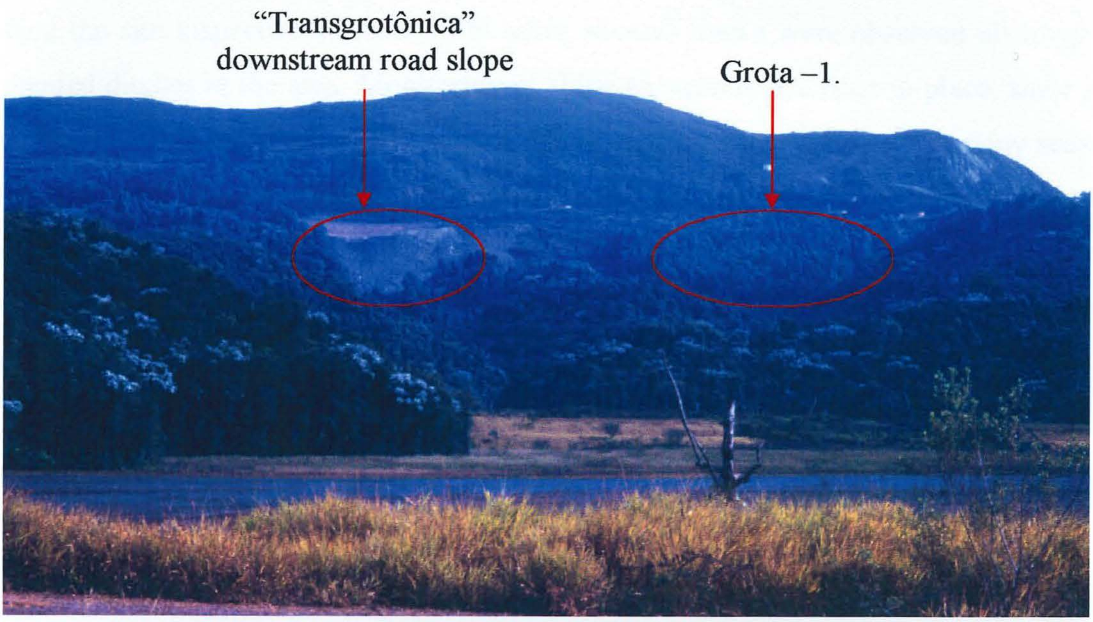

Plate 14 – View of the Downstream Slope of the Transgotônica Road where Cracks were Observed.

There are drainage elements all over the area, ranging from water diversion structures along roads to peripheral channels on dam and dumps abutments. The latter were usually built with boulders, taking advantage of both the size of mine equipment and quality of the rock. These channels are over dimensioned and integrated to the surrounding environment that will pose no problems for closure and post-closure periods. MBR has a good programme to evaluate the drainage systems. The area is divided into eight hydrological basins and the drainage channels recalculated periodically considering long-term performance.

Most of the natural slopes at the vicinities of the mine are either intact or with minor interventions. The only exception is the slope besides the railroad loop, which has experienced two failures. The first, in 1972, occurred during excavation of the railway bed. Since then, the area is creeping, without significant displacement. In 1992 another failure occurred, involving a portion at the west side of the first failure zone. The area is partially rehabilitated, as can be seen from Plate 15, but it will require further improvement to reach the equilibrium required for the future use.

Evidence of downward movement (creeping) of the upper slope, however, was present during the site inspection in June 1999 when several cracks were observed all long the cemented ditches in the area. Monitoring of slope movement has been in place, since just after the accident in January 1992, with frequent site inspections during the rainy season. At closure, the railway terminal will be dismantled, but due regard should be paid to the unstable slope. Although the moving slope is not considered by MBR a potential risk to public security, a passive care plan should be adopted and construction avoided in the area.

Plate 15 – View of Loading Loop of the Águas Claras Railway Terminal. The development of the railway created instability on the cut slope near the main entrance to the Mine.

The MBR's Environmental Management System

A competently prepared environmental management system (EMS) is a useful tool, which may assist mine management to meet both current and future environmental requirements and challenges. An EMS should provide a structured method offering management an improved view and control of the organisation's environmental performance to be applied from planning and exploration through to mine closure. The review of the EMS adopted by MBR was conducted to assess the ability of the system to support the company in achieving the closure objectives for the Águas Claras Mine.

Findings indicate that the environmental management team has a good knowledge of the environmental performance indicators used to measure progress towards achieving targets and the objectives of the rehabilitation. Unfortunately, no manual or tabulated lists with targets, objectives and regulations exist nor were environmental performance indicators in agreement with involved stakeholders. In the absence of these MBR would find it difficult to respond promptly to any demands placed upon it by the regulatory authorities and to reassure stakeholders about its ability to manage mine closure effectively.

Measures adopted by MBR to close the Águas Claras Mine started in the late 1980s with the Águas Claras Village project – a joint proposal developed by MBR and Design Workshop, Inc. from Denver, Colorado, USA. The main idea was to create an urban settlement, as shown in Figure 11, so that minimal disturbance and maximum integration with the surrounding environment could be achieved. Although it could be adopted for the post-mining use the site, this project has not been proceeded with, as yet. The possibility that it could be developed, however, remains. Other alternatives, such as a convention centre, were still being studied at the time of the site assessment in 1999. An interview with MBR's Director of Development revealed that company strategy has been to overcome the concept of "designing for closure" by developing post-mining sustainable use, rather than just a closure plan for the Águas Claras Mine.

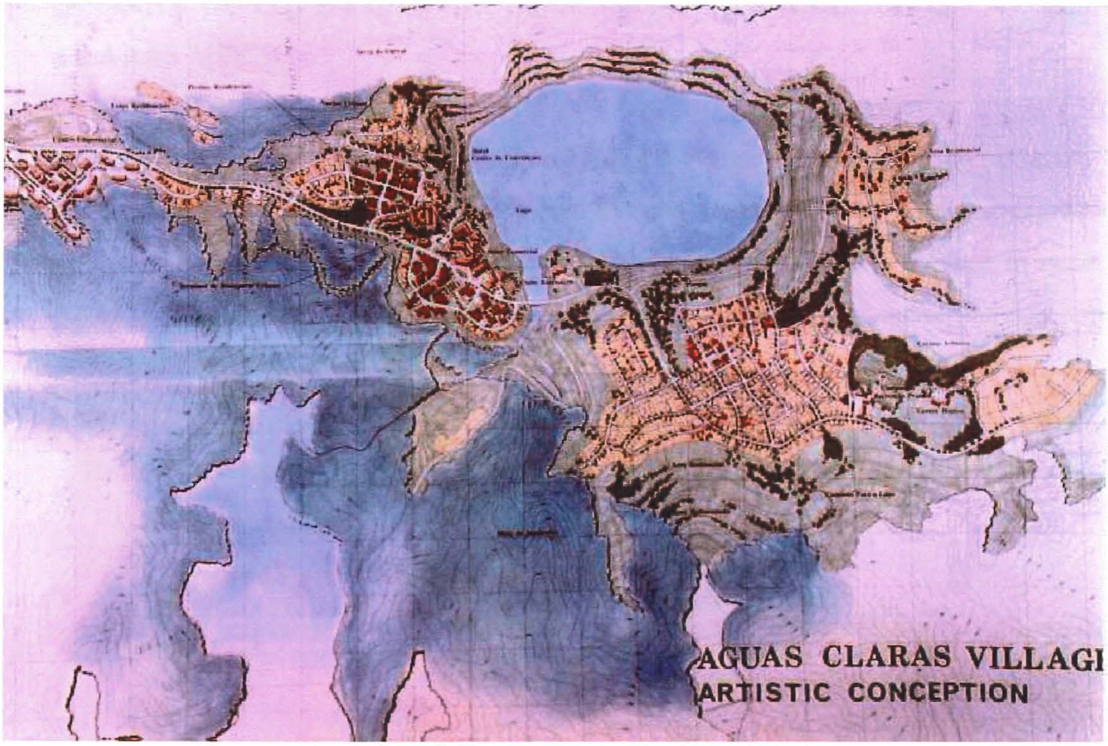

Figure 11 – Layout of Águas Claras Village. (Figure Courtesy MBR).

Two other measures that relate to the closure process have been taken. These were an analysis of the possible lake water quality conducted in 1995 and a simulation of the effects of the lake on pit slope stability. Individual members of the management team from MBR, however, were responsible for the decisions to adopt these measures, as a group to coordinate the closure process did not exist at the time of the site visit.

Closure of a mine is a complex procedure involving and drawing upon a variety of different disciplines. Therefore, to ensure a successful closure of the Águas Claras Mine, MBR should establish a closure team to focus on all demands of the closure process as well as to manage other projects such as the custodial transfer of the site. The Águas Claras Mine Environmental Follow-up Group already has some experience in this field and their knowledge will serve as a guide in establishing a closure team for the mine.

SUMARY OF POTENTIAL CLOSURE ISSUES AND LIABILITIES AT ÁGUAS CLARAS MINE

The closure issues and liabilities relating to the Águas Claras Mine components are summarised in Table 22. It should be noted that the danger of slope failure appears to be common to each component. Measures to be implemented during closure in order to avoid physical instability and hazard to public health and safety for each mine component are suggested in Table 23.

Table 22 – Summary of Main Liabilities at Águas Claras Mine

Mine Components and EMS	Liabilities
Open pit	Slope failure in the Northeast and South wall mainly during lake filling, long-term quality of water, security, wave effect in the in-pit lake.
Patrimônio Peak	Slope failure, rock fall.
Waste rock dumps	Slope failure, long-term water erosion, and drainage systems failure.
Sedimentation ponds	Over topping of structures, long-term water erosion on the dam slopes, drainage systems failure, and security.
Tailings dam # 5 facilities	Long-term water erosion, over topping of structures, failure of spillway and diversion works, gully erosion on cross-pond dikes, security of the site.
PFF dike	Slope failure, water erosion.
Infrastructure (roads, railway terminal, power lines)	Long-term water erosion on bare areas and roads, slope failure.
EMS	Absence of manuals or tabulated lists with targets, objectives and regulations; absence of environmental performance indicators in agreement with involved stakeholders.

Table 23 – Closure Measures to Achieve Physical Stability and Public Security

Mine Components	Physical Stability	Public Security
Open pit and Patrimônio Peak	Prevent deep-seated failure particularly during lake filling. Revegetate on slopes. Install steel net to avoid rock displacement on Patrimônio slope.* Provide adequate surface water drainage.*	Provide emergency access to lake. Restrict access with fencing. Signpost.
Waste rock dumps	Doze crest or construct toe berm to flatten overall slope.*	
Sedimentation ponds	Increase freeboard to prevent erosion by overtopping. Ditch, berm or fences to prevent erosion by motorized vehicles.	Restrict access to pond with ditch, berm or fence. Signpost.
Tailings dam # 5 facilities	Increase freeboard and/or upgrade spillway to prevent erosion by overtopping. Ditch, berm or fences to prevent erosion by motorized vehicles. Re-concrete the spillway for long-term stability. Establish a long-term monitoring and maintenance programme.	Restrict access to lake, slopes and spillway with ditch, berm or fence. Signpost.
PFF dike	Drain and contour the entire area.	
Infrastructure (roads, load out loop, power lines)	Remove culverts, barricades, approaches and stabilize. Rip compacted surfaces and establish vegetation. Restore drainage patterns. Remove unused power lines and transformers.*	Follow specifications for maintenance and prevent inadvertent use. Discharge and lock all non-essential power lines.*
Buildings	Decontaminate where necessary, disassemble and remove all equipment and buildings.* Backfill excavations. Remove buried tanks. Restore natural drainage.	

* Measures already implemented during site inspection in 1999.

The most important component in terms of liability and custodial transfer is the pit and lake that will be created. As reported in Franca (1998b), the lake will have a positive impact on pit slopes. However, during pit filling, special attention should be given to ensure their physical stability. The situation at Patrimônio Peak is of great importance and is a potential long-term liability, since pit slopes will require monitoring and maintenance during lake formation. Special attention should be paid to the northwest sector – slope failures on Patrimônio Peak will undermine public confidence. Therefore, the stability of the pit and Patrimônio slopes requires that a closure plan for the mine includes an active care and maintenance programme especially, during pit filling.

The time taken for the pit to fill is critical when considering implications for the stability of slopes. Preliminary studies by MBR suggest twenty years for complete formation of the lake. A more precise time scale should be determined and means to accelerate the filling of the pit should be better investigated.

The long-term stability of Tailings Dam 5, with its cross-pond dikes and spillway, should be carefully considered. This should be based upon estimates of likely outcomes, taking into account the factors involved as well as past experience elsewhere in the world. For these structures, a good post-closure maintenance and monitoring plan should be designed with an emphasis on the future use of the area. The plan should not omit or underestimate the vulnerability of the area to erosion processes and should address the frequency of inspections and the necessary maintenance of the spillway, ditches and diversion works. There is no such thing as a "walk-away" solution to such situations. There is, in fact, an ongoing permanent liability associated with them. The same programme should be applied to the PFF Dike, drainage systems of the waste dump and the sedimentation ponds.

The size of the mine site and its proximity to populated areas make the security of the mine site a cause of concern to be considered for the period after closure. A closure plan for the Águas Claras Mine must include a security plan to be followed in the post-mining use.

The post-mining use of the Águas Claras Mine area has not yet been determined. The first proposal for the area was the creation of Águas Claras Village. Other proposals include an extension of Mangabeiras Park, an extension of Jambreiro Forest and a conference centre development. The last option has been studied by MBR directors along with others received from the business community for alternative economic utilisation of the area.

Independent of the alternative land use, however, each different mine component has its own characteristics and limitations for post-mining use that have to be, separately, considered in a closure plan.

Table 24 summarises the expected closure performance of each mine component that will have to be accommodated within any post-mining use of the area. These include physical issues such as demolition, re-profiling and revegetation, stability of slopes and dams, effective drainage systems and control; chemical factors including water quality, oil and grease clearance as well as the major question of the extent of the success of revegetation, which must be an intrinsic part of the closure plan.

Table 24 – Expected Closure Performance at Águas Claras Mine

Components	Targets
Open pit / Curral Mountain range's spur	No deformation or erosion of slopes and benches; Water management system functioning effectively; Security arrangements functioning properly.
Process plant	Demolishment, Re-profiling and revegetation successful; Secure covering of foundations.
Waste rock/overburden piles	No deformation or erosion of slopes; Acceptable drainage water quality and quantity; Adjacent groundwater quality acceptable; Successful revegetation.
Tailings management facilities	No deformation or erosion of dams; Efficient dam drainage; Acceptable tailings geochemistry; Effective management system for surface water; Acceptable surface and groundwater quality; Security arrangements functioning properly.
Water management facilities	Rehabilitation and revegetation successful; Effective surface drainage of the site.
Landfill/waste disposal facilities	No deterioration in groundwater quality; cover secure; Successful revegetation.
Buildings and equipment	Demolishment, Re-profiling and successful revegetation.
Infrastructure	Re-profiling and revegetation successful.
Exploration areas	Successful reinstatement of drill and access roads.

Suggested Risk Assessment

Following there is a summary of the suggested risk assessment at the Águas Claras Mine.

Waste dumps

- Failure of the overall deposit, considering the internal drainage working satisfactorily.
- Failure of the overall deposit, considering the internal drainage collapsed.

Dams

- Hydraulic Risks assessment considering the probability of occurring overtopping in the event of insufficient spillway capacity for the maximum probable flood
- Structural Risks assessment considering the integrity's problem of the dam.

Pit

- Wave effect in the in-pit lake. Although previous analysis of stability of slopes demonstrated that the risk of failure is negligible (Franca, 1998b) it is judge to assess the effect of a wave created by a sudden slope failure would make in the lake and on the lake spillway.
- Lake induced seismology. Although previous seismological studies realized at the site have shown that the area low seismicity, typical of stable tectonic plate, five events were recorded, in locations more than a 100 km apart, with magnitudes between 4 e 4.5.

Therefore, studies involving the following steps should be considered:

- Tectonic characterization of the mine and surroundings, under the neo-tectonics point of view;
- Characterization of seismicity in the area, with analysis of the recorded events;
- Geomechanics characterization of the area, to provide basis for analysis of the potential for occurrence of induced seismic events;
- Design of a seismographic monitoring system.

CHAPTER 8 – SUMMARY, RECOMMENDATIONS AND CONCLUSION

MINE CLOSURE ISSUES

The challenges facing the mining industry today are many. Foremost amongst them are the continuous search for new reserves, additional limitations on access and the difficulty of obtaining mining rights, ever more prescriptive environmental regulations and, potentially, the associated compliance costs. In addition, successful mine closure is becoming a major preoccupation within the industry, as well as a measurement of performance by stakeholders. The pressure to be acceptable to all stakeholders is increasing and it is becoming an economic and social necessity to close a mine in a responsible manner.

Despite recent progress in the management of environmental issues, the mining industry has still encountered much criticism. Although mining projects have positive impacts on society in the form of jobs, taxes and regional development, there are (at least temporarily) negative impacts such as noise, aesthetics and environmental degradation. The long-term or residual environmental and socio-economic impacts after closure depend on the industry's attitude towards the so-called "triple bottom line" approach, which pays attention to financial and corporate, as well as environmental and socio-economic concerns. Planning for closure ensures that long-term environmental and socio-economic effects of a mining project will be minimised.

A closure plan, as an essential part of developing a mineral resource, is paramount in ensuring that mining companies embrace both the concept of sustainable development and the commitment to care for the environment. In the past, the life of a mine, however, has generally been understood to be the amount of ore reserve divided by the production rate. The concept of mine closure, on the other hand, extends the life cycle of a mining project until completion of the closure. The main objective of a cost effective closure plan must be to reduce the need for and extent of post-closure activities. This is most effective when designed into the pre-feasibility study from the very beginning of a project. In doing so, provision for rehabilitation activities can be set aside or utilized during the production phase when cash flow is positive.

The overall objectives of mine closure programmes for both mining companies and regulatory authorities are to protect public safety and health, minimise environmental damage, reach self-sustainability of the land after mining, minimise socio-economic impacts and reduce the risk of further environmental liabilities. Thus, closure programmes must address the mine components themselves, the surrounding environmental conditions and local socio-economic factors. The principal components of a closure plan are detailed project description, clear closure objectives, progressive rehabilitation measures, long-term monitoring and maintenance plans and financial insurance.

Danielson and Nixon (1999) noted two great impacts on the mining industry in countries where regulatory closure programmes have been implemented. One effect has been to encourage the spread of what is the minimum acceptable practice throughout the industry, something similar to a "floor of performance". Secondly, these programmes have pushed the newest ideas or led to the dissemination of best practice in the industry. These countries, however, still face issues that arise from the closure process such as the non-flexibility of most requirements and the long-term responsibilities for the "closed" mine site. Mining, as a dynamic process involving, for example, constant refinement of the understanding of the ore-body, changing definitions of reserves, development in technology and the prices of mineral commodities requires a flexible and easily amended closure process. The uncertainty about the requirements that mining companies will have to meet in the long term is a critical issue since some of them may be imposed retrospectively. In addition, there is concern about perpetual maintenance, for example with respect to acid drainage, which affects the competitive capacity of the industry compared with others in countries where companies are not forced to address the issue, see for example, Williams (1993). Mining companies expect that once the steps outlined in a closure plan are fulfilled, there will be no other major requirements. This clear understanding of long-term responsibilities allows companies to assign cost estimates with some confidence and, therefore, build it into their financial planning.

A general tendency for mine closure legislation is to be outcome-based rather than prescriptive. Prescriptive regulations set minimum standards and neither encourage continuous improvement, nor give the mine manager the discretion to develop site-specific solutions to rehabilitation problems. Codes of practice and guidelines are a preferred "regulatory" mechanism. A challenge to be faced by regulatory agencies and the mining industry is a matter of generic or site-specific completion criteria. The former can assist in achieving consistency throughout the industry, but the diversity of mining operations and ecosystems demands site-specific criteria.

Government agencies in a number of countries have adopted policies that require mining companies to provide an environmental financial surety for mine closure purposes. Financial insurance provides a guarantee that rehabilitation plans will be completed should the proponent fail because of premature closing, financial default or other causes. In systems that require financial assurance, the cost of maintaining the guarantee and the advantages of lowering or terminating it are considered strong incentives for companies to begin the closure programme and to follow it in every detail.

A RECOMMENDED FRAMEWORK FOR MINE CLOSURE IN BRAZIL

At present, the National Department of Mineral Production (DNPM), the Brazilian Mining Institute (IBRAM) and environmental agencies are working together on the development of a regulatory mine closure system. IBRAM has recently prepared a proposal for mine closure. The preliminary document puts closure management in the hands of DNPM. There is a conflict of interests in this proposal, since DNPM is also responsible for promoting the mining industry. This places the DNPM in the role of both public custodian and industry promoter – an indefensible position, since care for the environment is often seen to be in conflict with the profitability of the industry. Therefore, such incompatibility of functions should be avoided through active participation of all stakeholders in the development of closure regulations.

The importance of a mine closure programme, in Brazil, for both sustainable development and the success of the industry requires a positive participation by the sector in developing a new regulatory system. The mining industry should take a leading role in environmental issues and commit itself to protecting the environment in which it must work. Nothing less than this combination of positive proposals and the commitment to adopt them will produce cost-effective closure programmes. This could give the industry a reasonable amount of control over its destiny, as increased legislation or regulation will, surely, be introduced. How rational will the regulations be? Progress will be made, if the industry participates in the regulatory process on an ongoing basis and openly shows genuine concern for the closure issues.

Mining concerns must propose regulations that minimise closure impacts. Failure to make real reforms in the past has resulted in harsh regulations in the present. The destiny of the mining industry is linked inextricably to the environmental and socio-economic issues of closure programmes. As a strategy for mine closure, the industry should take an aggressive role in the public regulatory arena and commit itself to reasonable and effective mine closure. More than a public relations offensive, the mining industry should take a position of leadership in closure issues and promote its considerable expertise for developing effective guidelines and criteria for mine closure.

In general, the mining industry has the experience and knowledge to deal with the environment. Therefore, a strategy of compromise based upon a consideration of a range of alternative options should overcome the barrage of criticism from militant environmentalists by challenging their confrontational approach. An active stance can engage and direct the attention of the media, while regulators are likely to be more tractable when mining is perceived as environmentally committed. There are some realistic criteria for mine closure; the mining industry should seize the initiative and must propose them, by being open about its technology and liberal in sharing its knowledge and in disclosing all costs related to closure. Examples of such practices come from the Australian Mineral Industries Association (Tongway *et al.*, 1997; Tongway, 1998) and Alcoa of Australia Limited (Jarvis, 1998).

Bailey (1994) states "the risks associated with mine closure are particularly uncertain and have a potential to rise beyond expectation". Therefore, the goal of such an active strategy should be to create a compliance climate within which mining companies can operate. First, such a strategy should provide a framework for the Brazilian mining industry to develop solutions to actual, potential or perceived environmental, safety and financial issues associated with mine closure. Properly planned and managed, it can result in an easing of the burdens and costs of compliance while decreasing the impact of mine closure. This should ensure that closure costs actually make a positive difference in environmental quality and sustainability of post-mining sites. Invariably, this approach will mean that costs will rise, but the question is by how much and what will be accomplished. Secondly, rationalising and standardising the permitting process and simplifying the construction, operating, decommissioning and rehabilitation processes, while ensuring that environmental requirements are uniform from region to region, yet allowing for variations on a site-specific basis, should be the outcome.

CONCLUSION

Mine closure is a challenge for both the industry and the regulatory system in many countries. This is certainly true in Brazil, where many long operating mines are experiencing closure and regulatory agencies are preparing to impose such legislation. In addition to the discussion and analysis of the Brazilian regulatory system concerning mine closure, this study has focussed on the development of a Liability Assessment Programme to assist operating mines in planning for closure. The field research was conducted at the Águas Claras an MBR company mine of great importance in Brazil, which is scheduled to cease operating at the end of 2001.

The Águas Claras is a remarkable mine, particularly because of the high quality of its iron ore and is unusual because of its proximity to an urban area, the city of Belo Horizonte. Throughout its operational life, the mine has seen the growth of environmental concern in Brazil, particularly after the introduction of the regulatory requirement for EIA as part of the licensing process, while its imminent closure has triggered a general debate about mine closure in Brazil. The Águas Claras Mine has been a reference point in the debate between environmentalists and the mining industry. At the beginning of its operations in the 1970s, the vibration from blasting operations affected buildings in the Belo Horizonte neighbourhood. The prompt response of the company in changing the type of explosives and better blasting plans solved the problem and silenced its critics. Its mining operations in the Curral Mountain caused alterations to the line of the crest of the mountain and, in the early 1980s, resulted in a popular movement in Belo Horizonte against the MBR activities. The movement also pressed for the preservation of the Curral Mountain, one of the most beautiful views from the city. As a result, the Local Authorities declared Curral

Mountain a patrimony of the Belo Horizonte City recognised by law. The activities of this pressure movement coincided with the environmental debate in Brazil and adversely affected the image of the company. In response, MBR invested in environmental management and followed best practice in mining, as well as becoming more open in its dealings with the public and more involved with the community. The climax was the agreement between the Belo Horizonte City Council and MBR to restore the Plaza of Liberty, the most important square in the city. MBR covered the costs and took responsibility for restoring and maintaining the plaza. Such an enlightened attitude was a benchmark for social involvement and other companies soon followed their example. Since then, MBR has embraced an ethical policy and has been increasingly successful, thus 'doing well by doing good'.

Public consultation and disclosure of actions have allowed stakeholders to be informed of and involved in MBR's mining developments and operations. These actions have ensured the sustainability of MBR's activities in a region with a very sensitive environment and competing demands for land because of the proximity of urbanised areas. Today, MBR's decision to close the Águas Claras Mine and the procedures being adopted highlight the company's environmental, socio-economic and cultural sense of responsibility. Because of possible stability problems and visual impacts in the Patrimônio Peak and the likely public reaction, the company is leaving *in situ* approximately 90 million tons of iron ore, initially considered marginal, but now technically and economically mineable. The decision to not carry out the licensing process to exploit this reserve was made to show the company's good faith and its desire not to compromise other MBR's operations in the region. The Águas Claras closure will also serve as a benchmark, because of the company's determination to achieve the mine closure objectives, which go beyond the provisions proposed in the imminent Brazilian regulations concerning mine closure.

As noted by Robertson *et al.* (1998), custodial transfer of land, post-mining, requires an extension of the concept of designing for closure and the development of a post-mining sustainable use plan, rather than a closure plan. MBR's aims in the Águas Claras Mine closure process have been to achieve this objective. MBR, in addition to minimising the liabilities associated with Águas Claras Mine closure, has been actively participating in and spearheading leading efforts to implement mine closure practices in Brazil, by developing the custodial transfer process and seeking a sustainable post-mining land use.

Liability assessment is a standard practice in business with such programmes having been used during acquisitions or mergers. The approach could also be used in the identification and costing of mine rehabilitation liabilities. This would allow companies to know the precise cost and benefits in order to establish whether the expenditure is justified (Brodie, 1998). The programme developed in this research project and tested at the Águas Claras Mine had, as its objective, assisting mining companies assess their own liabilities and develop mine closure plans both to meet statutory requirements and to establish suitable environmental management objectives to close their operations in a responsible manner.

Liability assessment can easily be accommodated by EMS for achieving a successful closure, particularly for companies with a well-advanced system, such as the major firms like MBR. In these companies, internal staff given suitable training or supplemented by consultants can conduct such a liability assessment. Planning for closure, in Brazil, is a very new matter to most mining companies. Therefore, such liability assessment would be very beneficial by providing the necessary information for closure planning.

The liability assessment programme suggested to MBR and conducted on site identified the range of issues to be followed for planning effective mine closure. Besides its overall role in assessing closure liabilities, the results of such a programme can also be used for a number of other important management requirements. These include negotiation with government agencies and the community affected. Therefore, such an approach would improve the ability of the mining company to comply with the level of legal and financial liability resulting from the conditions imposed by mine closure regulations and stakeholders expectations.

The liability assessment is expected to help directors and managers demonstrate due diligence as well as recommending steps to be taken to ensure that all necessary management systems are in place to achieve closure objectives. In addition, in regulatory systems that require a closure plan and financial provision during the licensing process, liability assessments could be used to justify applications for tax deductions. Although not the case for MBR, this would be valuable for companies wanting to reduce financial assurance for mine closure.

The programme developed during this research and implemented by MBR represents an important innovation in mine closure planning for operating mines in Brazil. To date, mines are subject of this study – the Capanema Mine (an iron ore mine in Minas Gerais State) and the CLY Mine (a bauxite mine in Pará State). Although it will undoubtedly be refined and expanded in the future, it does provide an appropriate framework for future development. Subjectivity in the assessment is one possible criticism of this initial approach. Thus, research into the development of values to quantify the severity of long-term liability is one challenge for improving the programme. Improvements to reduce the level of subjectivity in the results will enhance confidence in cost estimates. The availability of data, the quality of the EMS in place, as well as better closure criteria are essential for a more robust liability assessment programme. The rate of change in both the regulatory environment and public attitudes poses a challenge to mining companies with respect to mine closure. Establishing robust environmental management systems, supported by liability assessment, will place the industry in a sound position to meet this challenge.

The situation with respect to mine closure is changing fairly rapidly at present. Research seminars, for example, are being held to explore the subject of closure planning. Thus, the findings of the Liability Assessment Programme conducted at the Águas Claras Mine during this research were presented at the First Iberoamerican Meeting on Mine Closure held in Spain in September 2000 (Lima *et al.*, 2000). Subsequently, the Brazilian Mining Institute (IBRAM), represented at this meeting, promoted the First Seminar on Mine Closure, held at the Águas Claras Mine Site in December 2000, confirming the importance of the mine to current thinking about the closure process in Brazil.

In the introduction to this thesis the hypothesis of using audit techniques for mine closure planning was outlined. The primary objective was to demonstrate the applicability of liability assessment for mine closure planning purposes. The Liability Assessment Programme conducted at the Águas Claras Mine showed it to be a practical tool for use within an environmental management system in planning for closure. The company's decision to proceed to the next stage and to carry out an assessment of the costs involved in following the recommendations of this study confirms the value of the approach. The findings and recommendations of the liability assessment report are already assisting MBR in designing a closure plan that encompasses measures to minimise the environmental, socio-economic and cultural consequences of mine closure. In addition, the expectation is that the results will be converted into a closure plan for the Águas Claras Mine complete with timetables, allocation of responsibilities and budgets. Thus, it is clear that this objective has been meet in full.

The programme proposed to the company had also as an objective an estimation of the cost of closure. Given a lack of time and information, it was not possible to investigate this issue totally. Field observation and discussion with mine personnel showed that to achieve this objective a number of measures should be conducted at the site as a prerequisite to estimating closure costs. These measures included a topographical survey of areas to be vegetated, graded and contoured, a survey of buildings structure to be demolished and a survey of contractor costs. Therefore, such a costing would require more time in field activities and personnel than the planned programme. In addition, lack of mine closure criteria for both the company and the environmental agency acts unfavourable against making estimates. This clearly indicates that further study of indicators of mine closure success is required.

The second objective was to outline possible key elements of a comprehensive mine closure programme in Brazil. An examination of mine closure regulations in US, Canada, Australia and South Africa, presented in Chapter 4 was the basis for the proposed framework. A comparison of these countries with Brazil allowed this objective be achieved. The key element in this framework is the role that the mining industry should play in establishing mine closure regulations in Brazil.

Suggestions for Further Research

Thus, the research programme has been largely successful in meeting its objectives. From this work, however, certain issues have emerged that require investigation to resolve the additional ideas that have arisen, to explore new concepts and to provide further data. First, there has been a number of mine closures in Brazil in the last 10 years. An evaluation of the current situation at these closed mine sites themselves, as well as the long-term environmental and socio-economic implications of the closures, would serve two functions. The results of this research could assist regulators and mining companies in the preparation of mine closure regulations for Brazil, as well as planning for future mine closures.

Secondly, there is a need for research jointly with the mining companies and environmental agencies to elaborate a list of indicators of successful rehabilitation. With these indicators, there is a need to develop a methodology to be followed by firms and regulatory agencies to assess whether completion criteria have been met. This research should focus on solving two issues: Are the particular criteria used appropriate for assessing the rehabilitation? Are the criteria relevant to the desired end use and to the community?

Thirdly, there is a need to consider closure implications in rapidly evolving technological areas such as tailings design and management for closure, geotechnical hazards assessment and the geomorphological assessment of rehabilitated lands. Thus, advances in these areas can feed rapidly through into closure planning.

There is a clear technical capability within the Brazilian mining industry to collaborate in such research areas. The academic research base is also present. Research in these areas is already being conducted in the School of Mines at the Federal University of Ouro Preto (UFOP), in Minas Gerais State, involving the Departments of Geology, Mining, Civil and Environmental Engineering. The introduction of mine closure issues into these research areas is feasible, since the university is pre-eminent in mining and geology teaching in Brazil, has an enviable reputation in research and strong relationship with the mining industry.

To date the author is running two research projects in the Mining Engineering Department within the Master Programme in Mineral Engineering. One involves the developing of a mine closure criteria database and the other, on financial guarantee to aid the government in developing and administering effective and practical financial guarantee policies. A questionnaire containing a number of specific issues about guarantees has been submitted to mining companies, environmental agencies and the DNPM. A paper with previous results of this research was submitted this month to Revista da Escola de Minas for publication.

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APPENDIX I – PRE-AUDIT QUESTIONNAIRE

GENERAL INFORMATION

1. What is the type and size of the mining project?
2. What are the operational components of the mine?
3. What are the current conditions and uses of the site?
4. What is the possible post-mining use of the site?
5. Does the company have an Environmental Management System (EMS)?
6. What are the potential impacts on human health and safety and the environment of the mining project?
7. Is there a monitoring programme in place? What does the monitoring programme cover?
8. Are there after care and rehabilitation programmes in place, in accordance and approved by a recognised body?
9. How many mining components are going to be involved in the closure process?
10. Have geochemical and geotechnical studies concerning the engineering properties of soil or rock been performed?
11. Have studies been made regarding stability analysis, considering both the short and long term?
12. Are they available for consultation during site visit?
13. Have studies concerning the hydrology (surface and ground water) of the mine site been made?
14. Is there a social communication programme, which makes provision for liaison with the community involved, hearing their concerns and attempting to understand their problems as well as encouraging them to become familiar with mining operations?
15. Does the company encourage and support liaison communities?
16. Is there any sewer treatment systems installed?
17. Is there any oil and greases treatment systems installed?
18. Is site investigation carried out on a regular basis and records kept?

MINING OPERATIONS

1. What are the dimensions of the pit?
2. What is the proposed post-mining use for the pit?
3. What is the expected amount of ore and waste to be extracted from the pit?
4. Has the mine instruments to control dust, noise and vibrations installed on the pit?
5. Has the mine instruments to control slope stability installed on the pit?
6. Has studies concerning underground water been made in the pit?
7. Who is responsible for operating and recording dust, noise and vibration controls?
8. Is site investigation carried out on a regular basis and records kept?
9. What will be done with mining equipment after closure?
10. Have geochemical and geotechnical studies concerning the engineering properties of soil or rock been performed?
11. Have studies been made regarding stability analysis, considering both the short and long term?
12. Have appropriated slope configurations (gradient and length) and the factor of safety of slopes (>1,2) been designed and checked?
13. Is there a drainage system which collects the surface water on the slope, and is it connected to an external drainage network?
14. What are the nature and quantities of wastes produced?
15. How many tailings dams does the mine have?
16. What type of tailings dam are they?
17. What is the capacity of them?
18. Have the tailing dams monitoring to control stability installed?
19. What will be the final use of them?
20. Have geochemical and geotechnical studies concerning the engineering properties of soil or rock been performed on the tailings dams?
21. Have studies been made on the tailings dams regarding stability analysis, considering both the short and long term?
22. How many waste dumps does the mine have?
23. What is the capacity of them?
24. Have any waste dump already been completed and rehabilitated?

25. What is the process of construction of the waste dumps?
26. Have the waste dumps monitoring to control stability installed?
27. What will be the final use of the dumps?
28. Have geochemical and geotechnical studies concerning the engineering properties of soil or rock been performed on the dumps?
29. Have studies been made on the waste dumps regarding stability analysis, considering both the short and long term?
30. What will be the post-mining use of the processing plant itself and its site?
31. Will the buildings be demolished and foundations buried?
32. Will the demolition works be conducted by the company or by contractors?
33. What will be done with processing plant equipment?
34. What will be done with reagents and other chemical products from the processing plant?

APPENDIX II – LISTS OF DOCUMENTS REVIEWED

1. Águas Claras Mine 1998 Mining Plan.
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