# Documenting reclamation and closure of Ermelo coal mines (Mpumalanga Province): Implications for developing a national strategy for mine reclamation in South Africa.

by

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**Documenting reclamation and closure of Ermelo coal mines: Implications for developing a national strategy for mine reclamation in South Africa.**

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**Abstract**

The reclamation and closure successes and challenges of Ermelo Mine Services in Mpumalanga Province in South Africa are documented and evaluated. It was found that most of the impacts of the mine on the environment and the surrounding areas were associated with the operational phase of Ermelo Mines Services. Major impacts and concerns that arose during the closure were the stability of the mined areas, contamination of the surrounding area, contamination and pollution in the study and surrounding areas, particularly of ground water aquifers, visual impacts, particularly of the discard dumps and slurry dams, the decommissioning of mining shafts, and monitoring the environment following the mine’s closure.

It is apparent that reclamation has been effective particularly as a private concern was contracted to undertake aftercare, notably the re-vegetation of the dump. The aftercare activities have contributed to decreased surface runoff and a reduction in surface and ground water pollution, as well as greatly reduce dust levels. The implications of the findings from this study are presented, particularly in view of there being a strong need to develop a national strategy for mining in South Africa.

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# CHAPTER 1: INTRODUCTION

## 1.1. BACKGROUND

Destructive environmental impacts through mining activity often appear in newspaper headlines the world over (Mining Magazine, 1995). Some examples of recent of negative environmental effects from mining that have made media impact are at Summitville, Colorado, USA; a cyanide leak at Cambria Resource's Omail Operation in Guyana; the Austin Gold Venture mine; an unprofitable mine built at high elevations in the Toiyable Mountains, south of Austin, Nevada, that destroyed a pristine area, and the Mt Hamilton mine, which destroyed a 10,700 foot mountain in the north end of the White Pine range west of Ely (Great Basin Mine Watch, 2002).

In South Africa, early mines that have long been exhausted and abandoned are notorious for their legacy of sterilized and unstable land, fires and acid drainage (South Africa 2001a). Many of the previously mined areas in South Africa have not been rehabilitated, particularly the mine dumps in parts of Mpumalanga, which bear testimony to the province's coal mining history (South Africa 2001a); the T&DB Sarga Mines near Witbank are the typical examples (see Sowetan, 2001). Perhaps the most well known evidence for early mining are the towering dumps surrounding Johannesburg that are monuments to the pioneers and entrepreneurs who uncovered the richest gold deposits in the world (South Africa, 2001a).

Coal mining has partially contributed to the development of South Africa's economy, providing the impetus and fuel for industrialization of what was previously a largely agrarian country (Baxter & Wicomb, 2000). Coal was, and still is, the predominant energy source for power stations and during the country's years of (apartheid) isolation and economic sanctions, coal conversion technology provided the only legal source of petroleum, oil and gas (South Africa, 2001b).

The impact of mining activities on the land and the manner in which natural resources are affected is well documented (Harrison & Hester, 1994). Inadequate mining regulations, and when existing, their non-implementation in many countries (*e.g.* South Africa, Democratic Republic of Congo, Brazil) has meant that mines are often not rehabilitated after mineral extraction has been completed. Abandoned coal-mines in South Africa have negatively impact thousands of hectares of agricultural land through subsidence, underground fires, gas emissions, and surface and ground water discharges (Attewell, 1993). Negative mining impacts are documented to indirectly influence the lives of large numbers of people, by curtailing industrial and agricultural development, limiting housing and infrastructure development and placing ordinary people at risk on a daily basis (Mining Magazine, 1995). Unfortunately, derelict mining sites from earlier activities cannot be "wished away" and require substantial reclamation efforts (Chamber of Mines, 1996). One of the primary challenges of the world's mining industry is a pragmatic response to the rapid evolution of environmental consciousness and the need to protect and conserve natural resources (Fox, 1984).

Currently, a challenge for the mining industry is how mining and the protection of the environment can co-exist (Robbins, 1996). South Africa is a perceived world leader in deep mining, but in many other developing countries (*e.g.* Democratic Republic of Congo) mining process are thought to be understood less and there exists a tendency to leave the environment to fend for itself (South Africa, 2001b). In the nineteen-sixties, ordinary miners seldom considered the environment and the consequences of their activities thereon (Chamber of Mines, 1981). However, there has been a recent upsurge in social and political forces initiated by a concern for the environment (International Committee for Coal Research, 2000). Environmental concerns are now essential part of governance, particularly in more "developed" countries (*e.g.* United States of America, Australia), where stringent environmental legal frameworks exist (Toy & Griffith, 2001).

The need to reclaim and restore derelict mining lands is now accepted in South Africa as a priority by the government and other non-governmental bodies (South Africa, 2001a). In certain countries (*e.g.* United States of America, Britain, Australia), investing in improving environmental performance, is viewed as providing competitive economic benefits (World Commission for Environment & Development, 1987). Such countries have accepted that sustainable development is an integral part of their agenda, and are, therefore, pro-actively improving environmental performance, without waiting to be mandated to do so (Parrota & Knowles, 2000). It is, therefore, imperative that mining operations should be designed, run and maintained to the best professional standards rather than to those ways, which appear to be the most economic in a short-term view (U.S. Bureau of Mines, 2002).

The focus of the research for this dissertation is the South African coal mining industry; in particular on the closure of the Ermelo Coal Mine. Two methods for extracting coal are used in South Africa, namely: surface, open cast and underground mining. Each of the types of mining, and the abandoned sites that remain after extraction has been completed, have their own unique environmental problems and challenges that are identified below (Chamber of Mines, 1999):

a. Surface mines:
   - large-scale landuse change,
   - the removal and disposal of overburden,
   - the disturbance of hydrology and run-off,
   - acid mine drainage,
   - visual intrusion,
   - noise and blast vibration,
   - fly-rock and fugitive dust,
   - burning coal discard dumps,
   - air pollution,
   - transportation/traffic, and
   - the stability of the neighbouring network.

b. Underground mines:
   - direct damage to the site,
   - unstable spoil disposal sites
   - spontaneous combustion in spoil disposal sites,
   - the creation of large “lagoons”,
   - subsidence,
   - aquifer disturbance,
   - mine water drainage/disposal,
   - methane emissions,
   - fugitive dust, and
   - visual intrusions.

c. Abandoned mines:
   - methane migration,
   - flooding,
   - ground water contamination,
   - structural integrity, and
   - land rehabilitation.

Coalmines in South Africa have tended to be abandoned, after completion of the extraction process in a disturbed state, with limited or no reclamation (Baxter & Wicomb*,* 2000). The abandoned areas influence the lives of large numbers of people by curtailing industrial and agricultural development, limiting housing and infrastructure development, and health risks (Austin & Peter*, 1971)*. Baker *et al.,* (1995) view abandoned mines as "eyesores" that have destructive environmental impacts, and are an unwelcome legacy for the government (local and national), and communities to deal with. The past and, in some cases, continuing, negative impacts often severely damage the reputation of the mining industry (Elliot *et al.,* 1996). Mines, as a result, are often unwelcome developments, and developers are, consequently, often denied access to land, especially where potential conflicts with the environment are foreseen.

## 1.2. THE IMPORTANCE OF MINING

Mining and minerals have an essential role in global development, by raising and maintaining living standards (Laurence, 2001). Extracting minerals is one of the oldest and most important human endeavours, because it provides the raw ingredients for most of the World and, like agriculture, is the lifeblood of civilization (Eagles, 1984). The Earth has many natural resources on which humans depend, that can be mined (Table 1). Coal, oil, gas, and other mineral fuels are used for heating, electricity and numerous industrial processes (Juwarkar *et al.*, 1993) (Table 1). Non-fuel minerals such as iron ore, precious metals, industrial metals, and non-metallic materials, like sodium and potassium, are used in chemical and agricultural applications (Griffith *et al.*, 1996) (Table 1). Even the crushed stone used in road building and other construction projects must be mined. Mining affects our standard of living and impacts almost everything we do. A variety of items that are use in homes, offices, transportation, communications, and national defence all require minerals (U.S. Bureau of Mines, 2002) (Table 1). For example, more than 30 different minerals are needed to make a single television set or a telephone.

TABLE 1.1: Commonly mined materials and end uses (U.S. Bureau of Mines, 2002).

| **Mined material** | **End uses** |
|---|---|
| Coal | Generating electricity, making iron and steel, manufacturing chemicals and other products. |
| Sand and gravel | Building roads, homes, schools, offices, and factories. |
| Iron ore | Steel products (kitchen utensils, automobiles, ships, buildings). |
| Aluminium ore (bauxite) | Military aircraft, naval vessels, pots and pans, beverage cans. |
| Copper ore | Electrical motors, generators, communications equipment, wiring. |
| Silver ore | Electric and electronics circuitry, coins, jewellery, photographic film. |
| Gold ore | Jewellery, satellites, sophisticated electronic circuits. |
| Zinc | Die-casting, galvanizing brass, and bronze, protective coatings on steel, chemical compounds in rubber and paints. |
| Lead | Batteries, solder, electronic components. |
| Clay | Bricks, paper, paint, glass, pottery, linoleum, concrete, wallboard, spackling, pencils, microwavable containers, vegetable oil. |
| Gypsum | Concrete, wallboard, spackling, caulking, potting soil. |
| Phosphate | Plant fertilizers. |
| Salt (halite) | Cooking, drinking water, plastics, and detergents. |

Minerals are vital to any industrialized nation; the United States uses more than 3.6 billion tonnes of mineral materials yearly, or about 18,000 kg per person, with about half constituting mineral fuels and the other half being metals and non-metals (U.S. Bureau of Mines, 2002). Stable and economic domestic mining, mineral, metal, and mineral reclamation industries are essential to the economy and a country's national defence. The U.S. Bureau of Mines (2002) calculated that the value of processed (non-fuel) materials of mineral origin produced in the United States in 1994 totalled approximately $360 billion. It is estimated that during the lifetime of an average American, he or she will use (U.S. Bureau of Mines, 2002):

- 1,600 kg of aluminium,
- 360 kg of zinc,
- 11,300 kg of clay,
- 25,400 kg of steel,
- 360 kg of lead,
- 680 kg of copper,
- 12,200 kg of copper,
- more than 226,000 kg of coal, and
- more than 453, 000 kg of stone, sand, gravel, and cement.

In South Africa, for more than a century, the mineral industry, largely supported by gold, diamond, coal, and platinum production, has made an important contribution to the national economy (South Africa, 2001a). The mining industry has provided the impetus for the development of an extensive and efficient physical infrastructure, and has contributed greatly to the establishment of the country's secondary industry (South Africa, 2001a). In 1999, South Africa produced 55 different minerals from 713 mines and quarries; 44 mines produced gold, 11 platinum-group minerals, 60 coal and 74 diamonds (Chamber of Mines, 1999). Mineral commodities from South Africa are exported to 87 countries (South Africa, 2001b).

Mining is a major employer in South Africa and mining employment rates vary considerably in different provinces; 14% of those employed in mining are in the Mpumalanga province (Fig. 1.1). Given the importance of mining as an employer in Mpumalanga, it is obvious that the Ermelo case study is significant. In 2001, South Africa's mining employment rate by sector (*e.g.* employment in the coal mining industry) (Fig. 1.2) was 12% (South Africa, 2001b). As previously indicated, the mineral extraction industries play a critical role in the vitality of our country's economy, in our standard of living, and in our personal lives. It is, therefore, imperative to maintain the co-existence between economic development (mining) without damaging the environment. While mining is, by its very nature, destructive, it should never be an anathema to environmentalism (Kundu & Heiva, 1994).

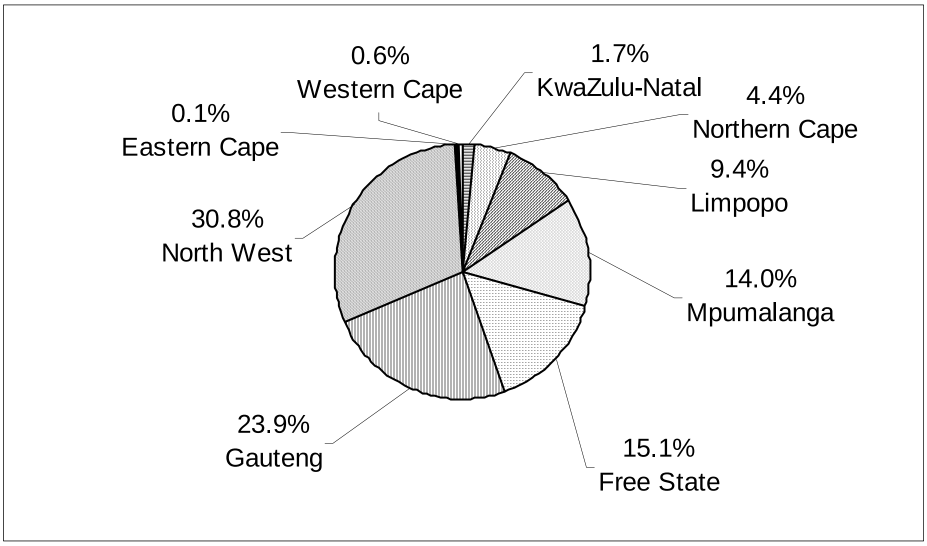


FIGURE 1.1: South Africa's mining industry: employment by province (South Africa, 2001a).

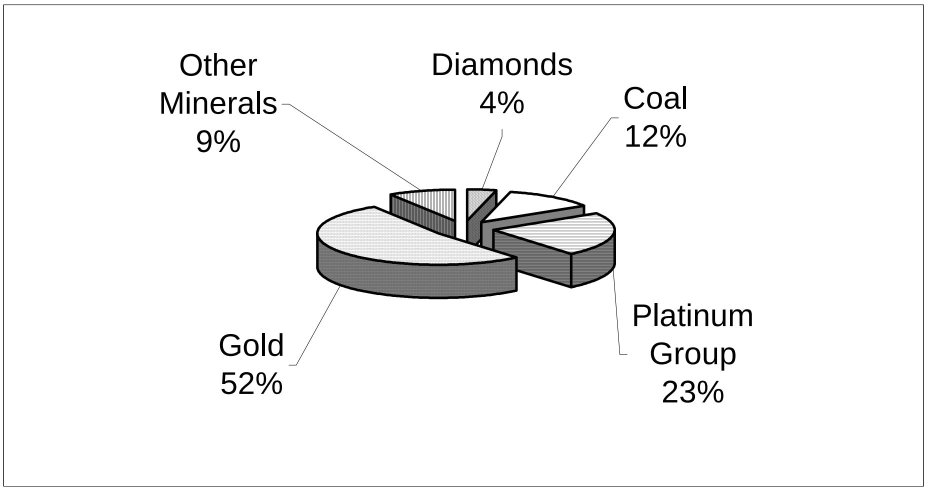


FIGURE 1.2: South Africa's mining industry: Employment by sector (South Africa, 2001a).

## 1.3. THE IMPACT OF MINING ON THE ENVIRONMENT

When mining takes place, particularly in the case of open cast mining, the land is usually cleared of all vegetation, the landscape drastically altered, and the ecosystem is, therefore, disrupted (Elliot *et al.,* 1996). If inappropriately managed, mining activities can also result in significant off-site impacts, particularly from the discharge of drainage contaminated with sediments, chemicals, metals or altered acidity (Owens & Cowell, 1994). Mining operations can also introduce pests, predators and diseases into natural ecosystems, and can open up isolated areas to further human-induced disturbances (Marcus, 1997). Mining affects a number of important elements of the environment that are discussed below (Elliot *et al.*, 1996).

### 1.3.1. Soil

The most important part of the land resource is the biological active portion near the surface, in other words, the soil (Anon, 1997a). Soil provides the rooting medium for plants and is the source of almost all the nutrients they require (Anon, 1997b). As vegetation develops to maturity over periods, so does soil; it often take centuries for the soil structure and fertility develop (Bradshaw, 1983; Anon, 1998b). Unfortunately the active soil-vegetation system is easily destroyed or degraded when mining processes produce derelict land (Anon, 1998b). In open-cast mining the soil is turned upside down and a thin layer of topsoil is usually contaminated with toxic or hostile substances from deep below the ground surface and, as a result, vegetative growth is harmed (Richter, 1993).

Mining waste is often dumped in steep-sided spoil heaps: the steep slopes are unstable and subject to erosion (Bradshaw, 1997). Handling and tipping very often result in compaction and loss of soil structure; some materials may be very fine and be left loose and porous (U.S. Bureau of Mines, 2002). Poor drainage or drought, particularly when it occurs often, exacerbates the already negative impacts of mining (Bradshaw, 1997). The damaged ground surface conditions may lead to extremes of surface temperature, wind erosion and sand blasting effects (Anon, 1998b).

Negative environmental impacts from mining often result in an inhospitable physical environment for plant growth. Added to these effects, are various potential chemical impacts that may negatively alter spoil characteristics that inhibit plant growth (Bradshaw, 1987), such as a reduction in nutrients or particular toxic problems (Anon, 1998b). Fresh waste material usually lacks the soil micro organisms and animals that are responsible for producing characteristics of soil that render it fertile medium for plant growth (Bradshaw, 1987).

Negative mining impacts on the soil could be overcome if the land is upgraded from its derelict state so that it is able to support soil development and plant growth, which are able to support mature and stable plant and animal communities (Bradshaw, 1997). Successful implementation of rehabilitation procedures allows the substrate to begin taking on some of the features of a fertile soil (Bradshaw, 1997). Plants will grow more successfully and in turn give rise to residues that will improve the physical and chemical characteristics of the substrate (Bradshaw, 1987, 1997). The beginning of the successful renewal of the degraded land resource is the aim of derelict land reclamation (Harrison & Hester, 1994).

Total extraction of an underground ore body may lead to surface subsidence that forms pans, and causes water-logging the soil or causes cracks in the overlying strata through which soil is washed though the breaks in the strata into the underground excavations to cause subterranean cavities and eventually sinkholes (Environment Australia, 1998). In all cases the water holding capability of the soil is detrimentally affected, resulting in a lower productivity capability (Street, 1986).

### 1.3.2. Water

Water pollution from coal mining presents a more complex problem than the large physical challenge of reshaping and rehabilitation (Elliot *et al.,* 1996). During mining people disturb the drainage pattern, which has established and stabilized itself over many years, thereby causing erosion (Griffith *et al.,* 1996). Materials are exposed which, although originally harmless, react with air and/or water to form hazardous wastes that pollute surface and ground water (Griffith *et al.,* 1996). Polluted water seeps out of the bases of discard dumps throughout coalfields; it is able to ooze from fissures in hillsides that were mined via ducts and underground tunnels that are above drainage levels (Richter, 1993).

### 1.3.3. Dust Pollution

In South Africa, mine dumps accumulate approximately 400-million tons of residues annually with a surface area of hundreds of hectares; this results in air pollution by dust, fortunately this dust has only nuisance value (Chamber of Mines, 1999). In addition, burning coal dumps and coalmines and stack emission at recovery plants, and smelters are particularly damaging in the atmosphere (Richter, 1993).

### 1.3.4. Biological Impacts

Mining destroys thousands of hectares of natural vegetation and habitat annually, through the deposit of residues and infrastructure development (Laurence, 2001). Habitats are directly lost through open cast mineral extraction, and that may have considerable consequent impacts on the local wildlife (van der Moolen *et al.*, 1998).

### 1.3.5. Social and Development Issues

The environmental and physical impacts of mines are severe and very visible, but also have a major impact on the lives of the local inhabitants and on the commercial and social development of the community at large (Bradshaw, 1987). Derelict land problems are not only concerned with a reduction in usable land surface areas, but also with the derelict land itself (Bradshaw, 1983). The presence of derelict land can have considerable effects over a very wide area. Each day, lives are put at risk as men, women and children walk across dangerous mining sites to reach schools and places of employment (South Africa, 2001a). Severe injuries and fatalities in South Africa have been attributed to people falling in crown holes or burning areas (South Africa, 2001b).

Mine dumps can dominate an entire landscape, which may be very unsightly (Attewell, 1993). The material that blows from the heaps may give rise to obvious dust in the air (Kundu & Heiva, 1994). Waste material that is burnt or catches fire spontaneously (*e.g.* coal waste) adds noxious gases to the atmosphere (Kundu & Heiva, 1994). Old mine workings can produce large quantities of acid drainage water containing toxic substances in solution that pollute streams, rivers and lakes (Bradshaw, 1987). Heavy rain can give rise to flash floods which cause severe erosion of waste heaps and severe contamination of watercourses (Anon, 1998b). The results of heavy metal mining in Wales, America and Australia in the last century still have their effects on aquatic organisms of streams that pass through the area, and there are many areas that are still degraded as result of mining in the early part of this century (Bradshaw, 1983).

All the above problems can combine, resulting in degraded landscapes. The effect that such landscapes have on humans often results from an irresponsible attitude towards the environment in which the community lives, in the form of litter, vandalism and a lack of planning (Alcoa World Alumina Australia, 2001). A rapid downward spiral of deterioration, then often takes place (Baxter & Wicomb, 2000). The deterioration can involve the land values, housing and job opportunities of a whole region (Baxter & Wicomb, 2000). Economic deterioration can be so great that there is complete collapse of communities (Bradshaw, 1983). Similar situations are clearly seen in the coal mining areas of the Appalachians (Chadwick & Bradshaw, 1980). Therefore, the ultimate challenge of derelict land problems and land restoration is to counteract all these tendencies and to bring about a complete environmental renewal. “As people we must learn to base our needs not on death, destruction, waste, but on renewal” (Berger, 1990:54).

## 1.4. RECLAMATION PHILOSOPHIES

Reclamation in any mining environment requires an overarching philosophy and rationale (Rainbow, 1987). If properly implemented, reclamation is one way to achieve sustainable development (South Africa, 2001a). The success of programs in Great Britain, United States and the decreasing derelict land surface areas in those countries, suggest that the reclamation of previously mined land is viable (Cochrane, 2002). An American reclamation expert's maxim was, "If you can't put it back like it was before you got it out, then don't do it", (Chadwick & Bradshaw 1980:64). The statement embodies the sentiments that land is a valuable and scarce resource that should be treated with care (Chadwick & Bradshaw, 1980). Wasteful use of land, or careless and irresponsible attitudes to land reclamation, cannot be condoned (Anon, 1998a). Therefore, mining industries across the globe should adopt the principle of Responsible Care towards the land and to voluntarily comply with environmental international standards (*e.g.* the ISO 14OO1). In addition, careful and thorough planning of landuse after decommissioning of mining operations should form an integral part of the mining operations (Baxter & Wicomb, 2000).

### 1.4.1. Establishing Landuse Objectives

The first task in developing an effective mine reclamation programme is to set a clearly defined post-mining landuse objective (Alcoa World Alumina, 2001). Reclamation programmes should be compatible with the surrounding landuse, they should support species diversity, be consistent with the expectations of the local community, and the landowners and regulatory agencies must agree to the implementation (Elliot *et al.*, 1996). An understanding of future landownership is critical (Bradshaw, 1997). Despite the best intentions, it might not be worthwhile trying to establish a productive landuse like fruit growing on undeveloped common land because maintenance of an area may become a major problem after mine decommissioning (Department of Conservation and Land Management, 1994).

When appropriate landuse objectives are set, then reclamation can commence (Stephenson & Sanders, 1996). First, the disturbed mined areas need to be returned to a safe and stable physical state that is integrated into the surrounding landscape (Cochrane, 2002). Safety should be considered in terms of risks to humans, domestic animals and wildlife, but the rehabilitated site should also reflect the surrounding landscape, if natural cliff faces or steep and rocky slopes occur locally, these features may be acceptable for aesthetic or habitat values (Nichols & Gardner, 1998). Stable soils are more likely to re-vegetate effectively and sustain productivity, and will maintain a protective cover over any hostile materials buried beneath them, such as acid-generating rocks or sub soils with toxic salt or metal concentrations (Fox, 1984). Stable soils prevents many off-site impacts; such as turbidity (muddiness) and siltation of watercourses (Shankar & Kapoor, 1993). Most reclamation programmes also involve some form of vegetation establishment (re-vegetation) (Bradshaw, 1997). Regardless of the landuse objective, the chosen vegetation must be productive and sustainable (Cook, 1990). If the vegetation is for commercial use, then productivity levels need to be competitive with similar enterprises on natural soils (Anon, 1998a). Where native vegetation is restored, productivity levels must be sufficient to establish and maintain a self-sustaining ecosystem (Gardner *et al.*, 1991). Restoration of species diversity can be a critical objective for reclamation programmes aimed at re-establishing native ecosystems (Davies & Bigg, 1995). Success in this endeavour is often dependent on first establishing the appropriate habitat and ecosystem recovery processes that will subsequently encourage the full suite of flora and fauna to re-colonize (Gaunt & Bliss, 1993). Possible landuses that follow successful land reclamation are (Davies & Bigg, 1995):

- the original landuse,
- agriculture,
- forestry,
- fish farming,
- intensive recreation and sport,
- extensive recreation and parks,
- nature conservation and wildlife,
- water storage and supply,
- housing and industry, and
- landfill and waste disposal.

The above are examples of reclamation where land that has been impacted on by mining operations and has subsequently been restored to its former or an improved condition (Giammar, 1997). Some experts believe that prior landuse should only serve as a guide in the development of reclamation and not strictly adhered to as the ultimate target because most mining regulations set the pre-mine landuse as the main target for restoration (U.S. Bureau of Mines, 2002).

Plans for using an area after mine decommissioning need not be the catalyst to begin reclamation, (Whiffen and Walker as quoted by Rainbow, 1987). Reclamation is generally undertaken either for economic or for aesthetic (topography inclusive) reasons

(Rainbow, 1987). The former vary widely and they range from the return to economics use by agriculture to planning of new industries (Rainbow, 1987). Examples include: housing development, road construction, increased amenity of the area, development of facilities for out door recreation and protection against wind and water erosion (Rainbow, 1987). The latter reason might be solely for preservation of nature and the improvement of visual impacts. There are many examples of land that has suffered the upheaval of mining and has been restored to its former use in the same way or in an improved condition (South Africa, 2001b). Other mining activities have been followed by reclamation to some form of biological productivity that represents a change in the landuse from its original condition (Anon, 1997a).

Agricultural land that has been disturbed through mining and tipping operations is often returned to productive forestry or vice versa (Giammar, 1997). If it is not appropriate to restore agricultural activity, an area can be restored for recreational purposes (*e.g.* playing fields, boating and yachting lakes) to provide amenity areas and public open space to allow areas to develop for conservation of wild species which can be used for education or to provide areas for housing, industrial purposes, public services and commerce (Laurence, 2001). Whatever final landuse is adopted following reclamation, it is imperative that it should fit in to the needs of the surrounding area and be compatible with other forms of landuse that occur nearby (Krige, 1993a). It is not sensible to establish grazing areas for sheep close to high density housing where domestic pets are severe threat to farm livestock (Rainbow, 1987). Similarly, it is not appropriate to establish nature reserves in areas where the need is for recreation and there will be heavy public pressure (Rainbow, 1987).

The eventual landuse following mining must take account of overall plans for the area (South Africa, 2001b). Further, the objective of reclamation needs careful scrutiny as it depends on the potential of the mined area and the resulting waste (Harrison & Hester, 1994). The disposal of waste should take account of the orientation and shape of the tips to be formed and the way in which different waste materials are deployed on site (Chamber of Mines, 1999). Waste disposal operations require knowledge of the chemical and physical properties of the waste material; to some extent this knowledge will place constraints on the formulation of ecological goals for the restored area (Parrota & Knowles, 2000). If the aim of reclamation is for re-vegetation, it is important to know that certain machinery employed in excavation and placement could seriously impede root penetration, which is essential for provision of water to plants, especially during dry seasons (Krige, 1993a). However, if site operations and re-vegetation procedures are planned well, there will be minimum delay between the use of the land for mining or waste disposal and its reclamation to some other form (Anon, 1997a). Too often, the time that elapses between the beginning of the use of site for mining or waste disposal and its eventual reclamation to some other use is a period of many years, so the whole of an area remains unsightly and unproductive (Anon, 1998b).

If the aim of reclamation is for development (*i.e.* the erection of buildings for residential or industrial purposes), then the product of soil construction must satisfy the following below-mentioned requirements (Harrison & Hester, 1994):

- It must be strong enough to support its own weight and the structural load on it.
- It must not settle or deform to the extent of causing damage to the structure on it.
- It must not undergo excessive swelling or shrinkage.
- Its strength must be retained permanently.
- Its physical and chemical characteristics must be environmentally acceptable.

## 1.5. BENEFITS OF MINING DERELICT LAND RECLAMATION

Land previously mined should be restored to biological productivity or to a condition where it can once again be utilized for a range of purposes valuable to a community (Marcus, 1997). Rehabilitated areas represent a direct improvement of the area on which the restoration has been carried out (Mining Magazine, 1995). In addition, the surrounding areas will also improve. The improvement of a site to a condition that integrates well into the surrounding landscape and removes intrusive landscape characteristics, upgrades the environment of a region far beyond the confines of the site that is restored (Moffat, 2001). Visual improvement of the mined out area can begin to upgrade a whole range of environmental characteristics: the built environment is kept in better repair, road surfaces and verges become worth maintaining, panning consents are more rigorously considered, there is less vandalism and the general appearance is respected (Berger, 1990). To improvement of a site can be added specific improvements of environmental conditions, reduction of dust burden in the air, reduction or elimination of gaseous additions to the atmosphere due to tip burning, reduction of particulate matter and noxious chemicals deposited in streams and water courses, and elimination of illegal tipping (Berger, 1990). The transformation that occurs in an area where planned and sensitive land restoration is practiced enables whole communities and areas to begin to upgrade social and economic conditions (Paulsen & Naude, 2002). One improvement will follow another and amenities and facilities are improved (Paulsen & Naude, 2002). However, it is difficult to provide a cost-benefit analysis of this situation although it is not difficult to find examples of where this has occurred (Baxter & Wicomb, 2000).

# CHAPTER 2: LEGISLATION

This chapter places emphasis on the gradual development of environmental laws in South Africa. In addition, a comparison is made between South African rehabilitation procedures and those in certain other parts of the World. In South Africa, much of the driving force behind the development of a consistent environmental policy and its associated legislation has stemmed from the international environmental law, and is now having to live and operate within an increasingly complicated and expensive framework of laws and regulations expressly designed to both protect and improve the environment (South Africa, 2001a).

## 2.1. DEVELOPMENT OF MINING ENVIRONMENTAL LAWS IN SOUTH AFRICA

The Mineral and Petroleum Resources Development Act, promulgated on the 1$^{st}$ of May 2004, is the cornerstone that promotes local, rural, social and economic development in South Africa (South Africa, 2002). Provision for equitable access to the nation's mineral and petroleum resources is enshrined as a principle of the current Act (South Africa, 2002). The Minerals Act, promulgated in 1991, was a major contributor in promoting optimal exploitation, processing and utilization of minerals within the constraints of sound environmental practice (South Africa, 2001a). An important component of all the recent "minerals-related" acts is adequate financial provision for reclamation during and after mining operations in all South African mines. However, in the old dispensation there were provisions of the Mines and Works Act 1956, regulation 5.12.1 and 5.12.2 that required only open-cast mines to submit rehabilitation programmes to be approved by the DME (Department of Minerals and Energy) and according to which rehabilitation had to be undertaken (Voogd, 2001). Rehabilitation was not linked to any mining authorizations and the only penalty one could incur for defaulting was a fine of R300 (South Africa, 2001b). With a growing awareness of environmental conservation worldwide, measures have had to be introduced to bring irresponsible operators to task and to ensure that all mines rehabilitate the effects of their mining operations on the environment, minimise pollution, and prevent the destruction of natural resources (Chamber of Mines, 1999).

Rehabilitation has been given a high priority in the Minerals Act (1991) and the Mineral and Petroleum and Resources Development Act (2002). The term "rehabilitation" is incorporated in the concept "environmental management" and is now more encompassing than previous definitions (South Africa, 2001b). Stringent requirements have now been established that deal with the commencement of new mining operations and also to the closure of old mines (Robbins, 1996). Companies wishing to commence mining must fully describe the pre-mining environment, compile a Scoping report, conduct an Environment Impact Assessment (EIA), and submit an Environment Management Program (South Africa, 2002). Evaluations of fauna and flora and soil types, ground and surface water quality and quantity, agricultural potential, and archaeological sites must be incorporated into a mine's EMPR (Environmental Management Programme Report) (South Africa, 1992). The EMPR outlines the actions to be taken and standards that are to be achieved in all operational phases from initiation of mining operations to decommissioning and closure. According to the International Association for Impact Assessment (IAIA), recognised areas of impact assessment should include (Voogd, 2001):

- Sustainability,
- Project Evaluation,
- Risk Assessment,
- Environmental Auditing,
- Technology Assessment,
- Social Impact Assessment,
- Health Assessment,
- Demographic Impact Assessment,
- Climate Impact Assessment,
- Ecological Impact Assessment,
- Environmental Impact Assessment,
- Environmental Management Systems, and
- Public Consultation/ Public Participation.

Previously, the *Aide-Me'moiré* document was used as a guideline to compile an EMPR, which has to be approved by more than one government department (*i.e.* Minerals and Energy, Water Affairs and Forestry, Agriculture, and Environmental Affairs and Tourism, amongst others) and other relevant authorities. The document was legally binding on the mining company; therefore, unless a mine's environmental management system is in order, a closure certificate will not be issued, and operators will remain liable for rehabilitation of the disturbed land (South Africa, 2001b).

## 2.2. THE MINERALS ACT 1991

The Minerals Act is built on three pillars, namely optimal exploitation, orderly processing and utilization of minerals (while providing for the safety and health of workers at mines), and the rehabilitation of land disturbed by mining or any related process (Richter, 1993). Application and administration of the Act regards each of the three pillars as being equal in importance. It is apparent that the DME is now concerned with the introduction of environmentally protective laws, unlike in the past, when rehabilitation received little or no attention in the planning of a mining project. Now, with considerable geological and technical knowledge at our disposal, the most profitable methods that ensure the safety and health of workers are carefully considered (Cochrane, 2002). Previously, mining practices led to endless problems for the Department of Minerals and Energy and the Department was considered liable when a company went bankrupt or an operator simply disappeared without rehabilitating a mine (Chamber of Mines, 1999). Currently, because in the Minerals Act rehabilitation is regarded as important as profits, and safety and health, it forms an integral part of planning in any mining developments (Cochrane, 2002). Rehabilitation is now considered at an early stage of the mining process, when a feasibility study of new mining project is conducted; the result is that an Environmental Impact Assessment is integral to the entire operation (South Africa, 2001b). When a mining layout is planned, capital is provided and during the life of the mine money is set-aside for rehabilitation (South Africa, 2001b). Therefore, sufficient funds should be available at any point in time to execute the full rehabilitation programme (South Africa, 2001b).

## 2.3. *AIDE-ME'MOIRE*

The Department of Minerals and Energy (DME) has long realized that it should not be necessary to burden the mining industries with negotiations with four or five different departments, each of which has their own agenda for the rehabilitation process (South Africa, 2001b). A holistic and integrated policy forms part of the DME vision in respect of rehabilitation of mines. In this regard, guidelines have been established for the preparation of an Environmental Management Programme Report (EMPR), published as an *Aide Me'moire*, to assist prospecting and mining entrepreneurs in the preparation of Environmental Management Programmes (South Africa, 2001a). The *Aide-Me'moire* was intended as a guideline document that aims to achieve the following objectives (South Africa, 1992):

- To meet the environmental requirements and directives of the Minerals Act, No. 50 of 1991, and its regulations;
- To provide a single document that will satisfy the various authorities concerned with the regulation of the environmental impacts of mining;
- To give reasons for the need for, and the overall benefits of a proposed project;
- To describe the relevant baseline environmental conditions at and around a proposed site;

- To describe briefly the prospecting or mining method and associated activities so that an assessment can be made of the significant impacts that a project is likely to have on the environment during and after mining;
- To describe how the negative environmental impacts will be managed and how the positive impacts will be maximized;
- To set out the environmental management criteria that will be used during the life of a project so that the stated and agreed land capability and closure objectives can be achieved and a closure certificate can be issued; and
- To indicate that resources will be made available to implement the environmental management programme.

In terms of the current Act (MPRDA), guidelines supplementing the *Aide-Me'moire* have been introduced (*e.g.* Environmental Management Plan (prospecting) and Environmental Management Plan (mining) to assist the applicants to compile the EMPR (South Africa, 2002). Applicants are further required to provide details of the quantum and the financial provision for rehabilitation should be itemized (South Africa, 2002).

## 2.4. AIMS OF THE ENVIRONMENTAL MANAGEMENT PROGRAM

The aims of the Environmental Management Programme have been defined by the *Aide-Me'moire* for specific categories (Table 2.1) (South Africa, 2002). It is clear that the aims are to operate in a manner that is as sustainable as possible. However, what are not included are aims that relate to the implementation of the objectives of the government and Department of Minerals and Energy policies.

## 2.5. RESPONSIBILITIES OF THE MINE HOLDER

The mine holder becomes responsible for compliance with all the provisions of the Act (MPRDA) relating to rehabilitation. A guiding principle of the controlling legislation is that the polluter (holder) pays for the costs of rectifying the impacts of pollution (Chamber of Mines, 1999; South Africa, 2001b). The same ideology is enshrined in the Rio Declaration on Environment and Development Principle 16: "*National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle bear the costs of pollution, with regard to the public interest and without distorting international trade and investment*" (South Africa, 2001a: 4). Other Acts, administered by departments that also have a bearing on mine rehabilitation, are the Water Act (1956), Atmospheric Pollution Prevention Act (1965), Conservation of Agricultural Resources Act (1983), Environmental

Conservation Act (1989), and the National Environmental Management Act (1998) (Cochrane, 2002).

TABLE 2.1: Specific aims for the South African Environmental Management Programme Report (South Africa, 2002).

| **Aspect** | **Aim** |
|---|---|
| Soil | To prevent subsidence and to establish stable land, profiled in such a way to prevent erosion and to prevent the pollution of both surface and groundwater by contact with contaminated water or potentially contaminant spoil or substances, creating land capable of achieving the predetermined, post-mining productivity and usage as close as possible to the pre-mining conditions. |
| Water | To establish a water management system that prevents erosion and the contamination and wastage of water resources and ensures compliance with the water quality management objectives as determined by the department of Water Affairs for the specific catchments area. |
| Air | To prevent dissemination of any form of pollution (including noise) emanating from any mining related process, operation or residue. Therefore attention is drawn to the rehabilitation of slimes dams and especially to the angle of outer walls that have a direct bearing on the permanence of the rehabilitation measures, particularly in respect of erosion and vegetation. It is important to achieve a stable and permanent cover on the dams and dumps. |
| Vegetation | To establish a stable vegetation cover, capable of natural survival and propagation. |
| Final Closure | To successfully adhere to all the requirements of the Mineral and Petroleum Resources Development Act in order to obtain the closure certificate. |
| Result | To leave the rehabilitated land as close as possible in a maintenance-free state, aesthetically acceptable and usable for future generations. |

Stringent environmental control systems are necessary in South Africa for the sustainable utilisation of the country's natural resources (Baxter & Wicomb, 2000). While it is accepted that mine operators transgressing the law should be prosecuted (Baxter & Wicomb,2000; Cochrane, 2002), the intention of legislation is that disputes are settled through negotiation and consensus (Baxter & Wicomb, 2000). The aim of mining laws in South Africa is that those involved in mining, even in the tentative stage of prospecting, will not be able to avoid a direct environmental responsibility (Krige, 1993b). It is intended that policy and principles are accepted and implemented throughout the entire life of a mine. Realizing that mines have finite lives, are place bound, and impact on the physical environment, the industry needs a strong commitment to protecting the environment (Attewell, 1993). In order to achieve an adequate balance between development and the environment, the objectives of a mining company should be clearly stated and be measurable in terms of environmental quality and quantity (South Africa, 2001a). The realisation is that mining in South Africa is part of "*a new game with new rules*" (Cochrane, 2002: 32); "the game" should be played in a transformed industry that aims to use the country's mineral wealth in a more accountable and responsible manner towards the environment (Cochrane, 2002). Mining companies should, therefore, not be defensive, but explain their policies, discuss environmental issues and involve the people (Chamber of Mines, 1999).

## 2.6. IMPEDIMENTS TO LEGISLATION

In many Third World countries, poverty is cited as the main reason for the disregard of environmental legislation (United Kingdom, 1989). The concern is that "*if third world countries adopt the type of stringent environmentalist policies Western countries now pursue, third world countries will never attain the hope of faster development*" (Shankar & Kapoor, 1993:27). On the other hand, people who are hungry are seldom concerned about the aesthetics of nature and are not moved by an ideal of ensuring sustainable development so that future generations are not compromised; "*they care more about today's dinner and tonight's shelter*" (Baxter & Wicomb, 2000:45). At present, the Third World is absolutely dependent on Western finance, markets and technology (Anon, 1997a). Such dependence gives leverage to the environmental levers; it could, therefore, be suggested that environmental conditionality be attached to loans and perhaps even private bank loans. It is an unfortunate reality that so-called "Developed Nations" have an unfair advantage over under-developed countries and are, therefore, able to exhaust Third World natural resources (Anon, 1997b). It is unlikely that existing unfair international trade practices will be easily relinquished (Anon, 1997b). As a result of the unfair trade practices, environmental controls are viewed by some countries with hostility. Even though South Africa and many developing countries are on a learning curve in terms of the environmental protection, it is clear that these countries do not wish to follow or emulate the Western path (Anon, 1997a).

One of the most serious problems encountered in South Africa is that insolvency of mining companies and the insolvency laws superseded the Minerals Act in Section 38(2) (Cochrane, 2002). The insolvency of companies is still one of the problematic obstacles the department of Minerals and Energy is facing today; for example, a company "Rand London" with mining enterprises in a number of South African areas was liquidated in London. However, all its operating mines were successfully making profits in South Africa. In KwaZulu-Natal, there are three collieries owned by "Rand London" that are now state entities, namely, Zoetmelksvlei, Kempslutand Aloe Minerals, but have apparent financial liabilities of approximately R20 million (Cochrane, 2002).

When a mining company runs into financial difficulties, the easiest option in South Africa is to liquidate and move into another region where the mining Directors would start a new company (South Africa, 2001b). All of the above experiences of the past have resulted in the development of the new Minerals and Development Bill, where not only companies, but the Directors, whether from the company or the State, will be held responsible for disturbance to the environment and water resources (South Africa, 2001a). Therefore, the state has ensured that it does not inherit the liabilities of rehabilitation by ensuring that adequate financial provision is in place equal to the disturbance created. Mining houses now seeking mining rights are required to ensure that adequate financial provision is made for rehabilitation after their activities have been concluded (South Africa, 2001b). The concept of creating a National State Rehabilitation Fund is also being considered (South Africa, 2001a).

## 2.7. OTHER LEGISLATION (UNITED STATES RECLAMATION LEGISLATION)

In the United States, each state is responsible for its mining policies, although all environmental regulations must be in agreement with federal Environmental Protection Agency (EPA) policies (U.S. Government's Bureau of Land Management, 2001).

### 2.7.1. Surface Effects of Underground Coal Mining: Minimum Requirements and Remedies.

According to US regulations on coal mining, the Regulatory Authority promulgates rules and regulations directed toward the surface effects of underground coal mining operations, and embodying the following requirements (U.S. Bureau of Mines, 2002). In adopting any rules and regulations, the Regulatory Authority considers the distinct differences between surface coal mining and underground coal mining. Each permit issued and relating to underground coal mining requires that operators (U.S. Government's Bureau of Land Management, 2001):

- adopt measures consistent with available technology to prevent subsidence that may cause material damage, except where the mining methods used require planned subsidence in a predictable and controlled manner. It is clearly stated that this does not prohibits standard room and pillar mining methods.
- seal all entrances and openings between the surface and underground mine working when they are no longer required for mining operations.
- fill or seal exploratory holes no longer necessary for mining, while, where possible returning mine and processing waste, tailings and any other waste from the mining operation, to the mine workings or excavations.

- stabilise all waste piles through construction in compacted layers using incombustible and impervious materials and also ensure that leachate will not degrade waters below accepted water quality standards.
- ensure that the topography of the waste accumulation is compatible with natural surroundings and that the site is stabilized and re-vegetated appropriately.
- operate all existing and new coal mine wastes according to the standards and criteria developed by the regulatory authority.
- establish permanent vegetative cover, capable of self-regeneration and plant succession that is at least equal in extent of cover to the natural vegetation of the area following mining operations.
- protect offsite areas from damages that may result from mining operations.
- eliminate fire hazards and otherwise eliminate conditions that constitute a hazard to health and safety of the public.
- minimize hydrologic disturbances at the mine site and in associated offsite areas during and after coal mining operations and during reclamation.

## 2.8. UTAH COAL REGULATORY PROGRAM (TECHNICAL AND FINDINGS REVIEW GUIDE 2002)

As already indicated above each State in the United States is responsible for its own environmental regulations. The Utah Coal Regulatory Program will be outlined and minimum requirements in terms of reclamation procedures will be examined.

### 2.8.1. General Minimum Requirements of Reclamation of Coalmines

A mine operator must provide a plan for the reclamation of the lands within the proposed permit area, showing how the applicant will comply with the regulatory program and the environmental protection performance standards (United States of America, 2002). The plan should include, at a minimum, the following information for the proposed permit area (United States of America, 2002):

- a detailed timetable for the completion of each major step in the reclamation plan,
- a detailed estimate of the cost of the reclamation of the proposed operations required to be covered by a performance bond, with supporting calculations for the estimates, and
- a plan for the backfilling, soil stabilization, compacting and grading, including contour maps or cross sections that show the anticipated final surface configuration of the proposed permit area.

- a plan for the redistribution of topsoil, subsoil and other material, along with a demonstration of the suitability of topsoil substitutes or supplements, should be based upon analysis of the thickness of soil horizons, total depth, texture, percent course fragments, pH, and area extent of the different kinds of soils, other chemical and physical analyses, field-site trials, or greenhouse tests if determined to be necessary or desirable to demonstrate the suitability of the topsoil substitutes or supplements may also be required (U.S. Government's Bureau of Land Management, 2001).
- a plan for re-vegetation including, but not limited to, descriptions of the schedule of re-vegetation, species and amounts per acre of seeds and seedlings to be used, methods to be used in planting and seeding, mulching techniques, irrigation, if appropriate, and pest and disease control measures, if any, measures proposed to be used to determine the success of re-vegetation, and a soil testing plan for evaluation of the results of topsoil handling and reclamation procedures related to re-vegetation (Marcus, 1997).
- a description of the measures to be used to maximize the use and conservation of the coal resource, a description of measures to be employed to ensure that all debris, acid-forming and toxic-forming materials, and materials consisting a fire hazard are disposed of accordingly and a description of the contingency plans which have been developed to preclude sustained combustion of such materials (Marcus, 1997).
- a description including appropriate cross sections and maps of the measures to be used to seal or manage mine openings within the proposed permit area.
- a description of steps to be taken to comply with the requirements of the Clean Air Act, the Clean Water Act, and other applicable air and water quality laws and regulations and health and safety standards (U.S. Bureau of Mines, 2002).

## 2.9. SPOIL AND WASTE MATERIALS

Specific regulatory requirements are specified for the management of mine wastes in Utah (United States of America, 2002); these are discussed below.

### 2.9.1. Disposal of Non-Coal Mine Wastes

Non-coal mine wastes that include, but are not limited to grease, lubricants, paints, flammable liquids, garbage, abandoned mining machinery, lumber and other combustible materials generated during mining activities should be placed and stored on a controlled manner in a designated portion of the permit area (United States of America, 2002).

Placement and storage should ensure that leachate and surface runoff do not degrade surface or ground water, that fires are prevented, and that the area remains stable and suitable for reclamation and re-vegetation compatible with the natural surroundings (Giammar, 1997).

Final disposal of non-coal mine wastes should be in a designated disposal site in the permit area or a State approved solid waste disposal area. Disposal sites in the permit area should be designed and constructed to ensure that leachate and drainage from the non-coal mine waste area does not degrade surface or underground water. Wastes should be routinely compacted and covered to prevent combustion and windborne waste. When the disposal is completed, a minimum of 2 feet of soil cover should be placed over the site, slopes stabilized and re-vegetated. Operation of the disposal site should be conducted in accordance with all local, State and Federal requirements. At no time should any non-coal mine waste be deposited in a refuse pile or impounding structure, nor should any excavation for a non-coal mine waste disposal site be located within 8 feet of any coal outcrop or coal storage area. Any none-coal mine waste defined, as “hazardous” should be handled in accordance with the requirements of any implementing regulations.

### 2.9.2. Coal Mine Waste

Reclamation of coal mines should contain descriptions, including appropriate maps and cross-section drawings of the proposed disposal methods and sites, for placing underground development waste and excess spoil generated at surface areas affected by surface operations and facilities (United States of America, 2002). Each reclamation plan should describe the geotechnical investigation, design, construction, operation, maintenance, and removal, if appropriate, of the structures (Giammar, 1997).

All coalmine waste should be placed in new or existing disposal areas within a permit area. Coal mine waste should be placed in a controlled manner to (United States of America, 2002):

- minimize adverse effects of leachate and surface-water runoff on surface and ground water quality and quantity;
- ensure mass stability and prevent mass movement during and after construction;
- ensure that the final disposal facility is suitable for reclamation and re-vegetation compatible with the natural surroundings and the approved post-mining landuse;
- not create a public hazard; and
- prevent combustion.

Coal mine waste materials from activities located outside a permit area may be disposed of in the permit area only if approved by the relevant authority. The disposal facility should be designed using current, prudent engineering practices and should meet any design criteria established by the Division (Griffith *et al.,* 1996).

### 2.9.3. Burning and Burned Waste Utilization

Coal mine waste fires should be extinguished by the person who conducts the surface mining activities, in accordance with a plan approved by the Division and the Mine Safety and Health Administration (United States of America, 2002). The implemented management plan contains, at minimum, provisions to ensure that only those persons authorized by the operator, and who have an understanding of the procedures to be used, should be involved in the extinguishing operations. No burning or unburned coalmine waste may be removed from a permitted disposal area without a removal plan approved by the Division. Consideration is given to potential hazards to persons working or living in the vicinity of the structure (United States of America, 2002).

After carefully conducting a literature review of coal mine reclamation in other countries, it is now possible to redirect reclamation challenges that mining companies face in South Africa. In order to improve or minimise the environmental impacts in the South African mining industry, research in the form of a case study (Ermelo Mine Services) was conducted and the research procedures, aims and objectives, the study area and data collection and methodology will be discussed in the next chapter, followed by the research case study.

# CHAPTER 3: ACADEMIC CONTEXT AND SETTING

## 3.1. RESEARCH PROBLEM

The study aims to investigate identified problems relating to mine rehabilitation in South Africa; the country is faced with many major problems, some of which are (South Africa, 2002):

- abandonment of mining areas without rehabilitation,
- inadequate Environmental Impact Assessment before, during and after mine closure,
- lack of adequate management of identified impacts,
- inadequate financial provision for rehabilitation, and
- a lack of monitoring and aftercare systems after post mine closure.

## 3.2. AIMS AND OBJECTIVES

Ermelo Mines are used as an example to investigate reclamation in the South African mining industry; at a superficial level it was seen as being representative. The general aim of the study is to evaluate the closure and rehabilitation of Ermelo mines and to specifically:

- verify whether an Environmental Impact Assessment was conducted and how the identified impacts were managed;
- evaluate monitoring and aftercare systems after post mine closure;
- contextualise issues at Ermelo mines with the whole mining industry in South Africa, and
- provide recommendations for a national strategy for reclamation and closure of mines.

## 3.3. THE PURPOSE OF THE STUDY

In South Africa, environmental problems especially in mining industries are diverse and escalating; therefore, the purpose of the study is to compile a documentation of the successes and failures of the closure of Ermelo Mine Services and provide a foundation for other South African mining companies to develop models for reclamation and closure. In addition, recommendations for amendments to the existing reclamation and closure policies are made in order to provide for a continual progression of environmental improvement in the mining industry.

## 3.4. THE STUDY AREA

Ingwe Ermelo Mines Services is located between Bethal and Ermelo in the Mpumalanga Highveld, in Tafelkop farm district in an area dominated by farming (Fig. 3.1). The study site lies within the Ermelo magisterial district and access to the mine is gained via the N17 and N11 routes. Ermelo Mines specialised in C lower seam bituminous coals (South Africa, 2002); the extraction of coal was conducted using an underground mining method and mechanized conventional coal extraction methods were used (Naude, 2002).

## 3.5. DATA COLLECTION AND METHODOLOGY

The study was qualitative in nature; interviews were held with selected officials:

- directors of the rehabilitation division,
- coal specialists,
- local authorities,
- interested and affected people ,and
- waste management personnel in the government as well as in Ermelo mine services were interviewed.

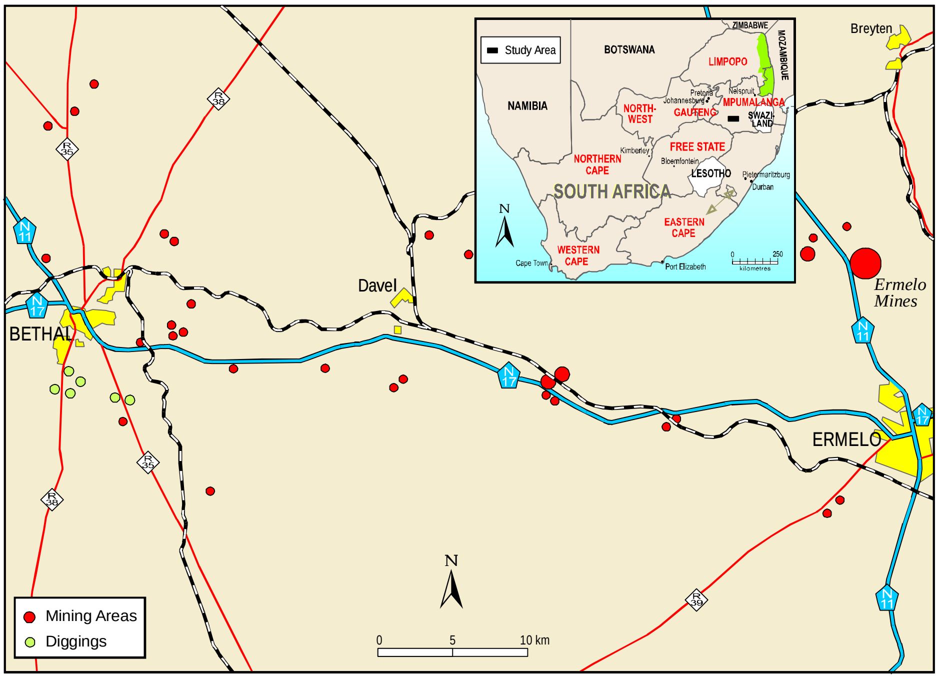


FIGURE 3.1: Locality map for the Ermelo Mines complex (Paulsen & Naude, 2002).

Site visits and spot check observations were also conducted at the mine. Supporting documents (*e.g.* surface subsistence study conducted by D.C. Oldroyd, geology study of the study area conducted by G.W. Blunden and the interested and affected parties meeting co-ordinated by Jannie Cronje and Amanda van Wyk) to the EMPR were examined and evaluated. The information relevant to the study is presented in the following chapter.

# CHAPTER 4: CASE STUDY: RECLAMATION OF ERMELO MINES

The emphasis in this chapter is on how Ermelo Mines Services tackled the challenges associated with reclamation following their decommissioning. As the mine was no longer producing coal, the most critical issue was to ensure that the remaining land should be rehabilitated so that it can once again be useful for future developments (Naude, 2002). Different reclamation methods were tried and those deemed fit were implemented in order to return the disturbed mining area to an environmentally friendly site that is sustainable and that can be useful to the future generations (Paulsen & Naude, 2002).

Ermelo Mine closure is still in process (no time frames for closure have been announced) and the mine committed itself to reclaim the affected mining areas to the satisfaction of the State and affected parties (Paulsen & Naude, 2002). After cessation of the Ermelo Mine's production phase, the following reclamation issues were attended to using various reclamation methods (Viljoen, 2002) (see Fig. 4.1 for orientation):

- The coal processing plant was demolished and reclaimed.
- The Remhoogte main shaft was closed and demolished.
- The Tafelkop shaft complex with its infrastructure was closed and reclaimed.
- The Tweefontein shaft complex with its inclined shaft and buildings was reclaimed.
- The ventilation shafts were closed and reclaimed.
- The coal discard dump presented a black ugly spot, which had to be reclaimed.
- Water supply affected by mining activities had to be remedied.

Each of the above challenges required specific reclamation methods and offered unique challenges that were outlined in the documentation of the processes (Paulsen & Naude, 2002).

## 4.1. RECLAMATION PROCESSES OF ERMELO MINE SERVICES

The processes discussed below form part of the reclamation processes which were implemented or conducted by Ermelo Mine Services; each site-specific reclamation process will be examined closely but separately.

### 4.1.1. Reclamation of the Coal Processing Plant

Although the coal processing plant required a sizeable chunk of work to rehabilitate, it also contained assets, which could be turned into capital to fund some of its rehabilitation liabilities (Paulsen & Naude, 2002). The liability was mainly the demolition of the structures, cleaning up of the dirty surroundings associated with the plant, rehabilitating the slurry dams used as silt traps when the mine was operating and reclamation of the stockpile areas (Viljoen, 2002).

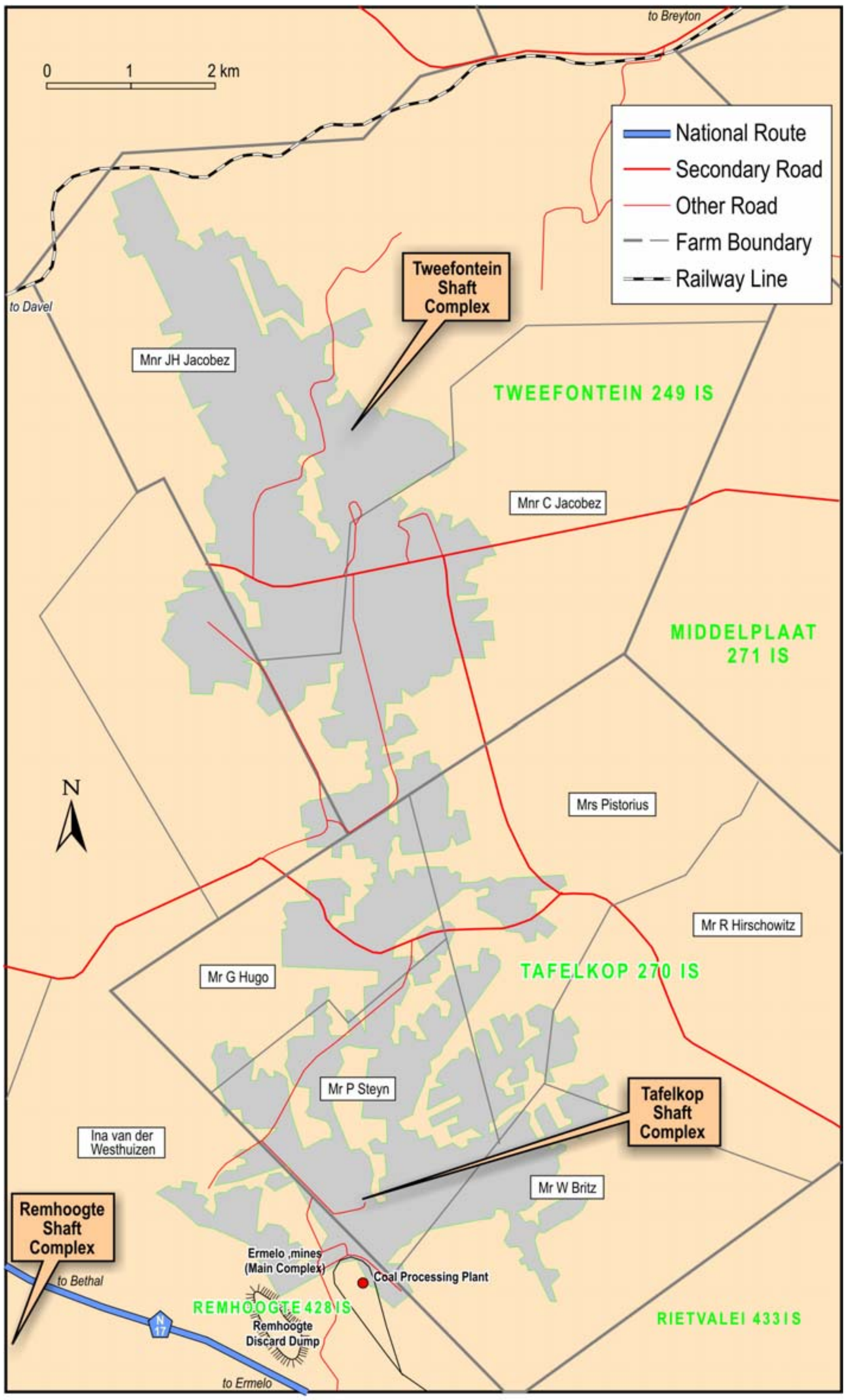


FIGURE 4.1: Topocadastral Map of Ermelo Mine Surface Infrastructures

Buildings that were previously used as offices, workshops and a training centre, offered ideal opportunities for future use (Naude, 2002). The main mine complex, the silos and associated conveyor system was not demolished but sold to an entrepreneur who intended to utilize it as a storage facility for grain (Paulsen & Naude, 2002). Silos had to be cleaned out before being handed over to the future owner (Naude, 2002). The bottom sections of the silos were filled with coal. Initial attempts to loosen the coal containing material in the bottom of the silos by blasting were not successful (Paulsen & Naude, 2002). The eventual method employed was to lower bobcats into the silos and excavate the material to the chute opening in the structures floor (Paulsen & Naude, 2002). To get these bobcats into the silos, a suitable mobile hydraulic crane had to be brought to the site to place and move them from the one silo to the other (Paulsen & Naude, 2002). The loose material was removed though the chutes at the bottom and the silos were washed to free them of any coal containing material (Naude, 2002)

### 4.1.2. Concrete and Slurry Dams

Concrete dams were used as thickeners and dirty water reservoirs; the coal slurry from the plant area was washed into the dams (Viljoen, 2002). The recovery of the plant equipment demanded careful planning and execution; after salvaging from the plant, equipment was stacked and stored in such a way that it could easily be found for potential customers to view (Naude, 2002). Where possible, the equipment was accompanied with a service history and associated literature (Naude, 2002).

Corrugated iron from the plant building was also stripped and sold (Paulsen & Naude, 2002). A demolition company used a technique called jet blasting to collapse the main support beams to bring down the plant building (Viljoen, 2002). Excavators fitted with grabs then separated the steel beams from the heap to cut it up in short pieces of steel (Viljoen, 2002). The steel was sold to scrap metal merchants (Naude, 2002). Once the steel was successfully removed, coal debris and concrete foundations were all that remained (Naude, 2002). The coal debris was removed and buried more than a meter below the surface (Paulsen & Naude, 2002). Concrete foundations were demolished with hydraulic peckers, mounted on the booms of excavators (Paulsen & Naude, 2002).

The raw coal and product coal stockpiles had to be reclaimed by shaping the areas to be free draining and then covering the area with a layer of topsoil (Naude, 2002). Slurry dams were no longer needed for their intended purpose and many were still very wet, making rehabilitation difficult (Viljoen, 2002). Rehabilitation involved first shaping the walls of the dams into the dams to flatten the area (Viljoen, 2002). The dams were then demolished to prevent ponding or wet spots when the area was completely reclaimed (Viljoen, 2002). When the shaping process was completed, the area was covered with a layer of topsoil (Paulsen & Naude, 2002). The final part of reclamation was the re-vegetation the area so that the area was ready for use by the future owner (Paulsen & Naude, 2002).

### 4.1.3. Reclamation of the Remhoogte Shaft Area

The Remhoogte shaft comprised sturdy concrete with a wide underground entrance (Naude, 2002). There was reluctance to demolish the shaft, which jeopardised the demolishing process (Paulsen & Naude, 2002). The winder conveyances, ropes and winder propelling gear were reclaimed (Naude, 2002). Once the valuable items were salvaged, the shaft headgear was demolished and dropped into the vertical shaft (Paulsen & Naude, 2002). All surrounding concrete rubble, which emanated from the demolition process, was dropped down the shaft (Paulsen & Naude, 2002).

The Remhoogte shaft area was not properly rehabilitated because the rubble materials used as filling was insufficient to stabilise the area (Chamber of Mines, 1999). International reclamation standards require that all portals, entryways, drifts, shafts and other openings between the surface and underground mine workings, should be sealed properly when not required (United States of America, 2002). A beacon was placed in the centre position of the shaft to mark its original position; a requirement for shafts that are closed (South Africa, 2001a). The buildings associated with the Remhoogte shaft were not demolished as they formed part of the complex sold to a private entrepreneur (Naude, 2002).

### 4.1.4. Tafelkop Shaft Reclamation

The Tafelkop shaft complex was rehabilitated by clearing of all structures associated with mining (Naude, 2002). First, the vertical shaft was stripped of the winder conveyances, ropes and winders (Naude, 2002). The steel headgear was taken down and sold as scrap metal (Naude, 2002). It was imperative to separate metal from other rubble, because corrosion may adversely effect the environment (United States of America, 2002). International standards require that non-coal mine wastes should be placed in a designated disposal site in the permit area or a state approved solid waste disposal area (Chamber of Mines, 1999). All concrete foundations and concrete slabs at Tafelkop were destroyed and dropped down the shaft together with contaminated soils and material (Viljoen, 2002).

International reclamation standards require that all contaminated soil and materials should be separated and buried with a protection layer to minimise the contamination of the mine site and the associated offsite mine areas (U.S. bureau of Mines, 2002). The Tafelkop area was shaped to smooth the contours, so that the landscape fitted visually with the surrounding areas (Naude, 2002; United States of America, 2002). The next step was to re-establish vegetation. A vegetation contractor re-vegetated the area and established the grass (Viljoen, 2002); currently the area cannot be recognised as a previous mine shaft complex.

### 4.1.5. Major Challenges of the Tweefontein Shaft Reclamation

The Tweefontein shaft complex required reclamation of the following structures (Paulsen & Naude*,* 2002):

- closure of the incline shaft;
- removal of the surface conveyor system and bins;
- clearing of refuse and unsightly mining remnants; and
- shaping of the steep and unsightly slurry dam area.

The incline shaft was closed by constructing a plug wall in the shaft entrance a few meters below surface (Viljoen, 2002). The area above the shaft plug wall was then filled with soil (Naude, 2002). Part of the closure process was to monitor the methane concentrations in the mine (Viljoen, 2002). Methane gas was first allowed to rise through the explosive range before it was considered safe. At the shaft plug, measuring pipes were installed to measure the methane content (Naude, 2002). The methane level rose as expected at the Tweefontein shaft area (Naude, 2002). Methane started leaking past the plug wall and some methane was measured in the shaft buildings (Paulsen & Naude, 2002). The rise of methane level could result in an unsafe situation if not addressed timeously. A problem was that the buildings were earmarked for use by a local farmer and they obviously had to be transferred to the new owner in a safe condition (Viljoen, 2002). International reclamation standards require that the mine out area should not cause the health hazards to the community (Mining Magazine, 1995).

The following dynamic processes could potentially have led to the reduction of free space in the underground workings at the Ermelo Coal Mine (Naude, 2002):

- Water seeping into the mine through the rock strata. This is a slow process but reduces the amount of open space of underground mine workings.

- If methane gas in the mine was released from the rock strata and escaped into the open space of the mine workings.
- If natural barometric changes associated with changes in the weather conditions, caused continuous pressure fluctuations in the underground workings. The result would have been that the mine could "breath in" fresh air (containing oxygen) and release methane gas when the pressure inside the mine workings became higher than the ambient pressure outside the mine workings (Naude, 2002). Methane gas is lighter than the other gasses and can, therefore, be found in the higher spaces, and as such it will be released first into the atmosphere (Toy & Griffith, 2001). The danger of oxygen entering the mine is that oxygen is one three components (oxygen, fuel and heat/spark) that commonly cause explosions (Schab & Postma, 2002). It was, thus undesirable, to have fresh oxygen entering the mine (Chamber of Mines, 1999).

The following measures were introduced to solve the problem of free space reduction in the Ermelo Coal Mines (Viljoen, 2002):

- The shaft area where the gas leaked through was inspected thoroughly and it was found that the sidewalls of the shaft were initially constructed using hollow cement bricks. Although the plug was properly sealed against the sides of the shaft, the methane gas escaped into the atmosphere through a conduit in the hollow bricks. The hollow bricks, from the plug to the collar of the shaft were removed, and the area was sealed with soil suitably compacted to resist the pressure from the gas.
- A monitoring borehole was opened to sample the water; a pressure release of gas (mostly methane) could potentially have escaped from the borehole. In itself the gas from the borehole could have resulted in an unsafe situation. The other problem is that the instruments used to sample water could have been rendered ineffective when dropped down the borehole, as the upward flow of gas may potentially have been sufficient to keep the instrument in suspension, preventing the sampler from taking the required samples. As such, it was necessary to provide pressure release points to cope with the continuous reduction of open space of the underground working which caused the pressure to rise.
- Special gas release valves were installed to release gas from the mine. The aim remained to increase the methane concentration of the gas in the mine (to get through the explosive range). To achieve the optimum build-up of methane and simultaneous release of pressure, the gas release valves were installed in

carefully selected positions in the mine to withdraw gas with a relatively low concentration of methane (Viljoen, 2002). Three boreholes were drilled for this purpose. One was positioned just above the water level; another was placed higher up on the roof contours of the mine, while the third was placed at a position presenting the highest position of the mine above the mean average sea level (Viljoen, 2002). The gas with relatively low methane concentrations was, thus, released to the atmosphere while the lighter methane was trapped in the higher lying areas of the mine (Viljoen, 2002). The gas release boreholes were constructed with a dual function; their primary purpose was to release gas, and second, when the water level reaches the borehole, they allowed water monitoring from the same borehole (Naude, 2002).

### 4.1.6. Tweefontein Reclamation

During the life of a mine, a considerable amount of scrap, rubble and carbonaceous material accumulates on the site (Paulsen & Naude, 2002). During reclamation, unwanted materials must be removed and the area cleared up. Generally, the ferrous metals are gathered and sold, but the non-usable materials and scrap are buried (U.S. Bureau of Mines, 2002). This was applied to Tweefontein and it can be argued that the reclamation processes were, therefore, in accordance with the international standards. The shaft was properly sealed, conveyors were removed, and the ventilation fan complex was cleared as required. The side slopes of the slurry dams were shaped to better withstand possible soil erosion (Paulsen & Naude, 2002). In the process, debris such as building rubble, pieces of conveyor belt and old steel wire rope were unearthed, and then re-buried, one meter below the surface (Paulsen & Naude, 2002). Redundant concrete foundations were also demolished and buried one meter below the surface (Naude, 2002). Burying the scrap one meter below the surface made it possible to work the area afterwards with farming implements (Viljoen, 2002).

The ventilation shafts at Tweefontein were reclaimed (Paulsen & Naude, 2002). The bulky fans had to be dismantled and removed and thereafter sold (Naude, 2002). The shafts were then sealed; sealing of all orifices into the mine is an important step to prevent exchange of oxygen and methane through the entrances in order to get the underground gas concentration through the explosive range (Naude, 2002).

#### 4.1.7. Reclamation of the Coal Discard Dump and Associated Remhoogte Rehabilitated Areas.

Discard dumps are generally the most prominent visible features remaining after a mine closes down (South Africa, 2001a), and can result in pollution problems if not rehabilitated correctly (Chamber of Mines, 1999). Pollution is generated from a dump if rain water is allowed to infiltrate the discard material with the consequential effects of water being contaminated as it migrates through the discard material and eventually decants on the toe line of the dump as a high saline and normally as low pH water (International Committee for Coal Research, 2000). Proper reclamation can, however, reduce the negative effects associated with discard dumps (Chamber of Mines, 1999). Insufficient reclamation prevents a mine from obtaining the closure certificate (South Africa 2001b). An un-rehabilitated discard dump associated with a mine can tarnish the image of the mining group, as the discard dump is directly associated with the mine (Viljoen, 2002). Rehabilitated dumps are image boosters (Viljoen, 2002). The purpose of the reclamation of the mine's discard dump is to turn the mine into something useful for the future; a self-sustainable project (Naude, 2002). In this regard, the Ermelo Mines Services discard dump was demarcated for agriculture, specifically livestock grazing (Naude, 2002).

The construction of the discard dump during the operating life of the mine can vastly reduce the amount of shaping required for a discard dump when the final reclamation has to be undertaken (Laurence, 2001). In the case of the Ermelo Mines Services discard dump construction was planned in such a way that the efforts in final shaping were reduced considerably (Paulsen & Naude, 2002). The Ermelo Mine Services discard dump was designed, located, constructed, modified, and rehabilitated in accordance to the reclamation standards and criteria developed pursuant to the international authority's regulations (Paulsen & Naude, 2002).

Reclamation of the Ermelo discard dump required proper design to ensure (Naude, 2002):

- safe access to the dump during and after reclamation;
- suitable water management structures on the discard dump and from the discard up to the natural water courses;
- minimisation of water ingress into the discard material and monitoring of pollution plume from the discard dump to the natural water courses;
- topsoil and vegetation requirements; and
- topsoil borrow-pit design.

### 4.1.8. Safe Access to the Dump During and After Reclamation

Safety is a priority when a dump is being constructed and when aftercare on the dump is undertaken (South Africa, 2001b). The final shape of a discard dump plays a major roll in enhancing safety (Laurence, 2001). In addition, if the long-term safety of the dump is not addressed in the design, it may then happen that the successor utilising the dump may encounter an accident or hazardous situations (Chamber of Mines, 1999). The purpose of appropriated design is to cater for the long-term use of the dump (Viljoen, 2002). The maximum inclination of the side slopes plays an important role in the safety of a dump. Naude (2002) stated that the Ermelo Mines side slopes were shaped to have a maximum gradient of 1:5 (Paulsen & Naude, 2002); farm implements can be easily used with these gradients (Naude, 2002).

### 4.1.9. Suitable Water Management Structures

The Ermelo Mines' discard dump covers 60Ha of land (Viljoen, 2002). A considerable amount of water falls on the dump during a rainstorm; if this is put in perspective: it means that for every 25mm of rain, 15000 tons of water falls on the dump (Viljoen, 2002). A certain percentage of the water is absorbed by the soil and later released by evaporation and evapo-transpiration (Paulsen & Naude, 2002). The remaining water finds its way through the soils (and discard material) to infiltrate the dump and end up as ground water (Paulsen & Naude, 2002). It is important that runoff from rainwater is accommodated in the drainage system of the dump (Paulsen & Naude, 2002). The design criterion that was used for the drains and contours in the Ermelo case was to cater for a storm event equal to the calculated regional maximum flood (Naude, 2002). Drain design on dumps can be problematic and require expert knowledge and design skills (South Africa, 2001a).

Historically, mistakes have been made with drain designs in the mining industry in general (Cochrane, 2002). Spiral contour drains were designed for the Ermelo Mines discard dump in order to minimise erosion. Spiral contour drains are considered unique to Ingwe and were previously implemented with great success on two other Ingwe mines (Paulsen & Naude, 2002). Spiral contour drains are easy to construct, and they reduce the margin for error that can occur during the construction phase (U.S. Bureau of Mines, 2002); they eliminate the need for specialised inlet structures and expensive runoff chutes (Naude, 2002). Ermelo spiral contour starts on top of the discard dump and spirals down the slopes of the dump until it reaches the natural ground elevation at the toe of the dump (Paulsen & Naude, 2002).

There are two main spiral contours on the dump with various smaller and shorter contours (Viljoen, 2002). The smaller drains followed the same design principles, but did not start on top of the dump (Viljoen, 2002). Approximately 70% of the runoff water drains to the north-west and the remainder to the south-east (Paulsen & Naude, 2002). Once the water reaches the natural ground level, at the toe line of the dump, it is channelled through armourflex drains into the natural streams (Paulsen & Naude, 2002). The water run-off if not properly channelled and treated may cause serious health hazards to people and the water eco-system, therefore, the water was treated and then channelled through the armourflex into the stream (Naude, 2002).

In addition to the implemented processes for closure it is suggested that the following options identified in South Africa, (2001b) would have facilitated the reclamation; preventing and removing water from contact with toxic materials and treating water drainage to reduce toxic content to be released to water courses. The two natural, watercourses on the north-western and south-eastern sides, run through a set of evaporation dams, which also capture other potentially, affected water (Paulsen & Naude, 2002). The evaporation dams are designed to spill only in high rainfall conditions, when there is abundance of clean water in the natural streams, providing sufficient water for dilution purposes (Laurence, 2001). Water should be properly channelled to avoid the release of contaminated water from discard dumps to watercourses.

#### 4.1.10. Minimization of Water Ingress into the Discard Material and Monitoring of Pollution Plume from the Discard Dump to the Natural Watercourse

Ingress of water into the discard material of a discard dump must be minimised to limit the effects of pollution (Paulsen & Naude, 2002). Water that infiltrates into the discard material starts of as clean rainwater and gets contaminated the further it seeps through the discard material (Laurence, 2001). When water on the discard dumps eventually decants at the lowest lying toe line areas, it is normally heavily polluted (Paulsen & Naude, 2002). Water pollution from discard dumps should be prevented as far as possible (South Africa, 2001b). One of the concepts applied universally is by way of cladding (U.S. Bureau of Mines, 2002); topsoil is used for this purpose.

The Water Research Commission, through tests, indicated that infiltration of both oxygen and water is effectively limited if the soil layer thickness is in excess of 500mm

(Naude, 2002). At Ermelo it was, therefore, decided to clad the dump with a layer of 500mm of topsoil (Naude, 2002). The topsoil used to clad the Ermelo dump contributed to the long-term sustainability of the dump, both as growth medium and as an impervious layer to prevent infiltration (Paulsen & Naude, 2002). Although the topsoil acts as an impervious layer to prevent water entering the discard material, it also acts as a "store and release" mechanism for rainwater, making water available to the plants (Paulsen & Naude, 2002). A farm adjacent to the dump was purchased to find suitable soil for the dump (Viljoen, 2002).

If swelling clay minerals are present in high proportions in a dump, uncontrolled infiltration through cracks in the clay is possible, which will limit growth by limiting release of water to the plants in dry periods (Viljoen, 2002). The soil used on the Ermelo dump was of near ideal clay content (Viljoen, 2002). Boreholes were constructed at different positions from the discard dump to serve as monitoring points (Paulsen & Naude, 2002). Samples were taken regularly, the soil physical and chemical properties were analysed, and the results recorded (Naude, 2002). By building boreholes as monitoring points, Ermelo Mine Services were acting in accordance with the international Standards and criteria to keep acid or other toxic drainage from entering the underground water (Paulsen & Naude, 2002).

*4.1.10.1. Topsoil and Vegetation Requirements*

The volume of topsoil placed on the discard dump and the associated reclamation areas was approximately 500 000$m^3$ (Paulsen & Naude, 2002). The bottom layers of the soil in the area of the discard dump were more of a gravel type of soil (Paulsen & Naude, 2002). The gravel soil, if mixed with the fertile top layers of the soil, has specific benefits that complemented the overall benefits on the soil used to cover the discard dump (Viljoen, 2002). The gravel type of material contains a relatively high concentration of trace elements that boost plant fertility, while the coarse particles in the soil mixture also limit raindrop erosion (Viljoen, 2002).

The selection of the grass species plays an important part in the vegetation process (Anon, 1997a). In Ermelo mines, the species selection approach was based on the following principles (Naude, 2002):

- The initial cover of grass had to be quick-growing to stabilise the soil against erosion, particularly when the soils were vulnerable to be washed away during the first summer rains; *Eragrostis teff* (known as tef) grows fast and was used.
- The soil of the dump had to be held together with creeper grasses. Horizontal growth, as with creepers, covers the area like a lawn if managed correctly. In this regard, the following creepers were introduced in the seed mix: *Cynodon*

*dactylon* (known as kweek) and *Chloris gayana* (known as Rhodes grass). On the contours, *Pennisetinum clandestinum* (known as Kikuyu) was introduced to offer more resistance to erosion.

- The initial management strategy was to graze the area after the second growing season. Strong growers, which are palatable for cattle and which can be cut and baled, were used for "high production pastures"; the species chosen included *Digitaria eriantha* (known as Smutsfinger) and *Chloris gayana*. During the first season the grass could be cut and baled; the area was later utilised for livestock grazing.
- At a later stage it is intended to introduce species of grass that are endemic to the area. The purpose is to slowly change the appearance of the dump to that of the surrounding natural environment. Should the dump not be managed intensively, it will revert to natural veld conditions (Naude, 2002). Grasses for this stage are *Melinis repens* (known as "fluweel grass") and *Themeda triandra* (known as Redgrass or "Rooigras") (Naude, 2002). The *Themeda triandra* is a highly palatable natural grass good for grazing (Naude, 2002).

The Ermelo Mine Services have apparently complied with the international standards by establishing a diverse and permanent vegetation cover capable of self-regeneration and at least equal in extent of cover to the natural vegetation of the surrounding areas on reclaimed areas and all other lands affected by mining.

*4.1.10.2. Topsoil Borrow Pit Design*

The borrow pits for stripping the topsoil were designed to be free draining and, when rehabilitated, leaving a landscape hardly recognisable as an area previously used as a borrow pit (Viljoen, 2002). The sides or boundaries of the borrow pit were designed according to the same principles applied to the discard dump, namely to have slopes not exceeding 1:5 (Viljoen, 2002). Excavation process were done to preserve the fertility of the soil in the borrow pit to ensure that the area can be used in the future (Paulsen & Naude, 2002). Strips of soil were left behind while the rest was removed and placed on areas where it was needed (Viljoen, 2002). The strips of soil that were left behind were then spread across the entire borrow pit area (Viljoen, 2002). By applying the above method, the soil containing organic matter and a portion of the natural seedbed was distributed across the borrow area (Naude, 2002). The resultant was that the topography was lowered to fit in with the landscape and had a limited influence on the soil fertility (Naude, 2002). Borrow pit areas were later seeded at the end of the vegetation project (Naude, 2002).

### 4.2. AFTERCARE OF THE RECLAIMED AREAS

Aftercare on the Ermelo Mines Services reclamation areas required that the following issues were addressed (Naude, 2002):

- aftercare management,
- cutting and baling of grass,
- weed control,
- erosion control,
- re-establishing of denuded areas with a suitable grass cover,
- grazing the area,
- fertilising and topdressing,
- establishing of fire breaks, and
- evaluation and auditing the re-vegetation process.

### 4.3. RECLAMATION OF THE WATER SUPPLY

Negative impacts from the underground mining activities are said to have affected farmers in the area of the Ermelo Coal Mine (Paulsen & Naude, 2002). As coal was extracted, the natural tendency was that the rock strata above the mined areas cracked and drained some of the water into the mine at a faster rate than normal (Chamber of Mines, 1996). The cracks apparently caused some boreholes to dry up as the water table dropped (Chamber of Mines, 1999). A further complication was that the subsidence of the surface topography resulted when remaining underground pillars collapsed (Viljoen, 2002). Where the subsidence reached the surface above the mine, the land was apparently impacted on; in a cultivated land area, it caused drainage problems and ponding (Naude, 2002).

During the life of the mine, some farmers experienced impacts on their water supply from boreholes (Paulsen & Naude, 2002). The mine then provided water to farmers by carting water to the affected areas, which became a full time job (Viljoen, 2002). Ermelo Mines Services committed itself to the successful solution of the problem that satisfied both the mine and the affected farmers. In order to solve the problem, the mine contracted specialists in the field of geohydrology and agriculture (Paulsen & Naude, 2002). Amongst others, a specialist in the agricultural field, a government related agricultural institute and the Ingwe Rock Engineering Department, provided valuable inputs for solutions to the problem (Paulsen & Naude, 2002).

Meetings were set up between the mine, farmers, and the consulted specialists (Naude, 2002). A framework for solving the encountered problems was agreed upon. The meeting involved the following steps (Paulsen & Naude, 2002):

- documenting case histories relating to the problem;
- obtaining the technical details of the mining activities, the boreholes, the farming activities and other relevant environmental related issues;
- quantifying the impacts up to then and estimating future potential impacts; and
- reaching an agreement on settlements or finding solutions to the problem.

The Ermelo Mine Services acted in line with the international reclamation standards by involving public participation in order to solve water problems and hydrologic balance at the offsite mine areas through water carting.

## 4.4. THE ENVIRONMENTAL MANAGEMENT PROGRAMME REPORT – CLOSURE PROCESS

The final Environmental Management Programme assessment report forms part of the standard practice when applying for the granting of a Closure Certificate in instances where a mine ceases to operate (South Africa, 2002). The focal point of this section will be the Ermelo Mine Services' closure plan.

Reclamation and closure of a mine are intertwined; one cannot happen without the other (Chamber of Mines 1996). The closure plan for Ermelo focuses on sustainability (Viljoen, 2002). Examples of some sustainability indicators are (Viljoen, 2002):

- Aftercare costs for the discard dump (all rehabilitated areas) must show a decline over time. Eventually, there must be no expenditure to support the rehabilitated areas.
- Trend lines for water quality samples, taken at strategic positions agreed with the State must show a definite improvement over time. Final values for water quality for water released into public streams must meet the agreed standards. An important issue here is that, if closure is applied for before the final state of equilibrium is reached, the water qualities as predicted by the consultants must be in line with field measurements. If the actual water qualities are in accordance with the predicted water qualities, it boosts the confidence levels and will give the State more reason to grant closure.

At the time of writing this report, the Environmental Management Programme Performance Assessment Report (EMPR) was in its final stages before being presented to the State for approval (Viljoen, 2002).

## 4.5. RECLAMATION CHALLENGES FOR MINING INDUSTRY IN REACHING MINE CLOSURE

Reclamation challenges based on the past experiences in mining will be outlined and future anticipated reclamation challenges in South Africa would be discussed below.

### 4.5.1. Key Issues from the Past

Mine closure and its reclamation are interdependent because one cannot happen without the other, therefore both should be given equal attention (South Africa, 2001a). In South Africa, ground and surface water pollution have provided the most common problems (van Zyl, 1999). Several South African mines have been awarded closure certificates and developed serious environmental impacts thereafter through water pollution (Naude, 2002).

In South Africa, new strategies need to be developed and implemented by the mining industry, the State, land owners, NGO's, and communities to work together to solve the problems associated reclamation challenges to attain mine closure (Cochrane, 2002). Much has been learnt about acid mine drainage (AMD) and that some of the AMD decants should be treated to meet legal standards and societal expectations (South Africa, 2001a). A major stumbling block to mine closure is to determine the legal and regulatory requirements (van Zyl, 1999). What makes the above more difficult is that the various authorities have differing requirements and expectations that are exacerbated by personnel changes (Naude, 2002). It appears that the state is not willing to make clear-cut decisions when it comes to mine closure because it fears that the measures implemented will not withstand the test of time and become a cost to the taxpayer (Viljoen, 2002). For example, is rehabilitation conducted effectively to ensure the change in landuse from mining to agriculture, or any other landuse (Viljoen, 2002)? The other problem is secondary mining by individuals who re-mine mine dumps that have just been rehabilitated (Viljoen, 2002).

### 4.5.2. Future Closure Challenges

The greatest challenge the mining industry face is to get a closure certificate when the mine closure plans approved by the state and other stakeholders have been implemented (South Africa, 2001b). In South Africa, while surface reclamation is preferred, underground mines or parts of the mines tend to be neglected (Cochrane, 2002).

Surface (and visible) components of Ermelo Mines were rehabilitated, but little was done about the underground workings. International regulations require mine holders to rehabilitate the surface and underground working in order to avoid subsidence (U.S. Bureau of Mines, 2002). South Africa needs clear guidelines that will provide direction for effective and efficient mine reclamation and closure (Naude, 2002). Many reclamation and closure plans have been caught up in a web of uncertainty and by the lack of decision-making criteria (Voogd, 2001). The cost of clear decision process to both industry and government is not appreciated and has not been quantified (Naude, 2002). When it takes longer than ten years to get a closure certificate, there is a clear indication of something wrong and people have to develop innovative procedures to break the drought of closure certificates so that people can move on and invest their time and resources on developments that can deliver jobs, returns and deliver people from poverty (Voogd, 2001).

Most of the past challenges were viewed from a technical mining and environmental perspective (Naude, 2002). A new era, of sustainable mine reclamation and mine closures arrived when South Africa hosted the World Summit on Sustainable Development in Johannesburg (Cochrane, 2002). From the Summit and other developments, notably the new Minerals Bill and the Mining Charter, new approaches to mine reclamation and mine closure were suggested (Paulsen & Naude*,* 2002). The best way to achieve the required mine closure results would be to develop the right "reclamation/closure habit" (Walde, 2002). The right "closure habit" should rest on four cornerstones, namely (Walde, 2002):

- knowledge,
- skills and ability,
- financial capability, and
- a will to do the right thing.

Knowledge refers to how to assess performance, understanding the relationship between cause and effect and being able to implement known mitigation measures that will deliver a known result (Walde, 2002). The skills existing in South Africa to apply established knowledge are limited. Therefore, some action is required in order to raise the implementation skills levels.

Most of the mines in South Africa *can* afford to close their mines sustainably, because adequate financial provision for closure requirements has now been put in place for existing mines; rehabilitation funds are apportioned to cover mine closure costs (South Africa, 2001b). For effective mine closure, it is essential that appropriate checks and balances are put in place (Walde, 2002). Even in a self-regulatory environment, one needs effective sanction against those who do not comply with the requirements on a voluntary basis (Viljoen, 2002). In South Africa, the government and the mining industry must develop a plan of action that will consider at least the following factors (Walde, 2002):

- A clear government policy developed in close collaboration with the mining industry, which addresses the key environmental issues.
- The issues surrounding co-ordination and co-governance that hamper implementation of the current system should be resolved at a government level.
- A systematic process for closure procedures should be developed. In this regard, reliance should be placed on best practice guidelines such as those already developed in Australia and other parts of the world.
- Regulations that provide appropriate checks and balances should be put in place.

It is important that the perception that mine closure represents anything more than relief from specific requirements of the Minerals and Health Act should be corrected (South Africa, 2001a).

### 4.6. CURRENT DILEMMA

The current legislation applicable to mine closure in South Africa has either changed or is in the process of being changed (Naude, 2002). Policies and guidelines are, however, still under revision or waiting approval of legislation to be updated (South Africa, 2001a). The major problem is that the success of the applicant for mine closure is thus judged in terms of the compliance with the requirements of the latest applicable legislation but the applicant has no written guidance on the method of complying with the new legislation in the form of both on policy and technical levels (Schab & Postma*,* 20002).

The mining industry as well as the department of Water Affairs and Forestry (DWAF) also experiences the dilemma of lack of clear guidance procedures (Voogd, 2001). Mines are constantly confronted with a lack of clear direction and guidance for the application of technical requirements. Proposed changes in legislation influence the requirements for improved water resource management and inconsistency in application of legislation, amongst others (Schab & Postma*,* 2002). The DWAF is confronted with a lack of technical information to support decision making, a continued risk of accepting unreasonable liability, uncertainty regarding long term sustainability, lack of capacity, and various other problems influencing the assistance to the industry towards mine closure objectives (Voogd, 2001). It is clear that the current situation is prone to lead to confusion, frustration and conflict both within the government departments and the mining industry (Walde, 2002).

The costly exercise to rehabilitate abandoned mines or remediation of pollution due to abandoned mining activities encountered by the DWAF does not reflect the current policy statements with regards to mine closure (Schab & Postma*,* 2002). It is, thus, clear that the way forward for rehabilitation and mine closure can not only be lodged in a "vision statement" but what is needed is practical way forward addressing the requirements of both the mining industry and still achieving the mandate of the DWAF by the development of clear, feasible and written guidelines on achieving a sustainable long-term solution (Schab & Postma*,* 2002).

## 4.7. THE WAY FORWARD

Currently, various new legislation, policies, and strategies are under revision or in development (South Africa, 2001b). Probably the biggest legislative influence on mine rehabilitation and closure is the current Minerals and Petroleum Resources Development Act (Schab & Postma*,* 2002). Furthermore, the development of the Mining Environmental Management Series (MEM) of guidelines is perceived as a positive incentive by the DME (Walde, 2002). The process of revising the Aide-Me'moire guideline and replacing it with an Environmental Management Plan (for reconnaissance and prospecting) and an Environmental Management Program (for mining) is a clear indication that the DME needs more guidance on mining technical requirements (South Africa, 2002).

# CHAPTER 5: RECOMMENDATIONS

The central focus of this chapter is the recommendations of mitigation measures in order to guarantee successful reclamation of derelict mines. As previously indicated, mining industry by its very nature generates significant pollutants that differ in type and volume. Therefore, it is imperative that the long-term environmental protection and management must be given priority over short-term economic gain (Giammar, 2002). The concern is underpinned by the legacy of past mining in many parts of the world. Recognition of the need for environmental assessment is also emphasized or contained in the Rio Declaration on Environment and Development, principle 17 states "Environmental impact assessment, as a national instrument, shall be undertaken for any proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority" (Attewell, 1993:65).

It is important to realize that the consumers pay for the amelioration of pollution, whether it is generated by the mining industry or by the consumers or by any other activities (Baxter & Wicomb, 2000). It has to be recognized that environmental improvement is justified on a quality of life and resources basis (Laurence, 2001). Continuing environmental damage arising from polluted waters and dispersal of contaminated solid waste is a feature of old mines in South Africa, North America, Australia and Europe (Chamber of Mines, 1999). It is, therefore, becoming standard practice for reclamation measures to be considered as an integral part of mine planning and operations, even to the extent that financial provisions are made during the operational life of mine to effect reclamation measures upon closure (South Africa, 2001a). The higher environmental profile attached to modern mining is linked not only to social acceptability but also to legal requirements in many countries (Harrison & Hester, 1994).

## 5.1. ERMELO MINES SERVICES

The recommendations in this section should be viewed as a complimentary process to supplement on Ermelo Mine Services' reclamation processes in order to achieve reclamation objectives as per the mining guidelines in South Africa. The recommendations below are the stepping-stones that are recommended, which would have improved Ermelo Mines Services' reclamation processes (Chamber of Mines, 1999):

- All disturbed areas are restored in a timely manner to conditions that are capable of supporting the uses they were capable of supporting before any mining or higher or better uses.

- The underground activities are consistent with the surface owner plans and applicable to local landuse plans and programs.
- The local authorities and interested and affected parties are encouraged to initiate and authorize the proposed landuse following reclamation.
- Additional drainage systems are installed at the disposal areas to prevent leaching.
- Water runoff from the undisturbed areas is not commingled with water runoff from the surface of the refuse pile or dump area.
- Organic material is used as mulch or is included in the topsoil to control erosion, promote growth of vegetation or increase the moisture retention of the soil.
- There should be no permanent impoundments on the rehabilitated dump.
- Monitoring boreholes and methane release valves are serviced regularly to control the concentration of methane and the contamination of ground water.
- The stability of disturbed areas is monitored annually to prevent unexpected subsidence.
- Armourflex drains and rock underdrains are constructed of durable, non-acid, non-toxic forming rock (*e.g.* natural sand and gravel, sandstone, limestone or other durable rock) that does not slake in water or degrade to soil materials and which is free from coal, clay or other non-durable material.
- Perforated pipe underdrains are corrosion resistant and have characteristics consistent with the long-term life of the fill (refuse pile).
- Where spontaneous combustion occurs in the future, (*e.g.* burning coal waste), waste should not be removed from the permitted disposal area without a removal plan.

## 5.2. OTHER RECOMMENDED MINING DERELICT LAND SOLUTIONS

Because derelict land includes a wide variety of materials, the methods of reclamation have to be tailored to specific problems of each material (Bradshaw, 1997).

### 5.2.1. Top Soil Conservation

The most obvious solution to the problem of derelict land is that “prevention is better than cure” (Bradshaw, 1987). If a area is to be disturbed by surface mining or tipping, the fertile surface layers of soil, the top soil (30cm) and sub-soil (60cm) have to removed separately and stored, and then replaced later where disturbance occurred, so that the original soil is restored immediately (Attewell, 1993). It is easy to do in a progressive, strip mining operation where the extraction operation moves quickly over the area taking a relatively thin layer of material, such as coal and sand lying under overburden (Naude, 2002). To expose the initial working face, the topsoil, subsoil and overburden must be dumped (U.S. Bureau of Mines, 2002). Thereafter the overburden can be removed and replaced when extraction is finished, followed by subsoil and finally topsoil, with sequent savings in handling, in a continuous, progressive operation (Bradshaw, 1987). Topsoil loses should be minimal and topsoil care should taken for future soil use (Anon, 1997a). In nearly all modern progressive operations, topsoil replacement will soon be standard practice and should be required by authorities permitting mining developments (Great Basin Mine Watch, 2002). However, in modern large-scale strip-mining it may be difficult and expensive to transfer the topsoil across the working face to the replaced overburden (Hoffman, 1997). It is possible that the overburden with a little improvement can form a better soil than the previous topsoil (Cochrane, 2002).

### 5.2.2. Top Soil Application

It may be possible to obtain good soil from a site that is being developed for other purposes and spread it over an area of derelict land from which the topsoil has been lost (Bradshaw, 1987). The process provides in one operation a fully developed soil, of good structure and texture containing an adequate store of nutrients (Anon, 1998b). The organic matter and nutrients constitute a buffer against any extremes of toxicity or other adverse factors that may be present in the derelict land material, and the good structure ensures satisfactory water retention even if the waste material underneath has a poor water retaining capacity (Toy & Griffith, 2001). As a result, establishment and growth of plants when topsoil is used as covering material are excellent (Toy & Griffith, 2001); planting can be spread out over a long period (Krige, 1993a). If the correct procedures are followed, growth after the period of establishment should be good, since the soil has a store of nutrients, which are released slowly (Bradshaw, 1987); aftercare, in the form of fertilizer additions, may not be necessary (Bradshaw, 1987). There is usually no need to know what is wrong with the material making up the derelict land, since the topsoil provides a totally new environment in which the plants can grow (Toy & Griffith, 2001). As a result, topsoil is an obvious and widely recommended solution (Chamber of Mines, 1999); it is one that appeals to many people, especially those who believe erroneously that topsoil has a unique quality that cannot be reproduced (Schab & Postma, 2002).

The question is: why is the above not the universal solution (Schab & Postma, 2002)? A simple answer is cost and availability (Cook, 1990). To be effective, the layer of topsoil must at least be 10cm thick (Baxter & Wicomb, 2000). That will be sufficient only to provide a good seedbed and a moderate store of nutrients for subsequent growth (Cook, 1990). Plants will have to be able to root into the underlying material and obtain much of their water and nutrient from it (Alcoa World Alumina Australia, 2001). To be totally sufficient, a grass sward will need at least 25cm (Shankar & Kapoor, 1993); trees will need far more. Loading, handling and spreading more quantities of soil, even with modern machinery, at present cost considerably more than $500 (± R3500) per ha and will cost much more when the soil has to be carried more than one or two kilometres (Bradshaw, 1987). Where such costs cannot be met out of immediate income in an active industry and the land is therefore truly derelict, they may be prohibitive (Elliot *et al.,* 1996). Even if finance is provided, people will ask whether it is appropriate to spend money in that manner, when it could be put to other aspects of the restoration such as the establishment of playgrounds, or even building houses or schools (Baxter & Wicomb, 2000). There are many situations, such as areas where there is a large amount of derelict land, where even if the money is available, the topsoil is not (Baxter & Wicomb, 2000); for example, in many mined areas around Johannesburg, the use of topsoil would mean that other areas would have to be made derelict in order to acquire the topsoil (Voogd, 2001). The same is true in remote country districts and national parks where there is no construction work that would provide topsoil (Voogd, 2001). However, where a large heap of waste is being reduced in height and spread over a larger area than it originally occupied it is often practical to remove the topsoil from the areas where the heap will be and then spread it back thinly over the whole heap (Bradshaw, 1997).

### 5.2.3. Re-vegetation

The objectives of vegetation establishment are: long-term stability of the land surface which ensures that there is no surface erosion by water or wind, reduction of leaching, lessening the amounts of potentially toxic elements released into local watercourses and to ground waters, development of a related landscape or ecosystem in harmony with the surrounding environment, and positive value in an aesthetic, productivity, or nature conservation context (Street, 1986). The approaches to re-vegetation can be described in terms of two different basic philosophies: (1) adaptive, and (2) agricultural (Harrison & Hester, 1994).

#### *5.2.3.1. The Adaptive Approach:*

The adaptive approach emphasizes the selection of the most suitable species, sub-species, cultivars and ecotypes to meet the rigors of the extreme conditions. It is not necessarily true that the mine wastes may be improved using amendments to achieve optimum establishment and long-term growth (Harrison & Hester, 1994). The approach is simple but is constrained by the availability of suitable indigenous species in some areas.

*5.2.3.2. The Agricultural and Forestry Approach:*

Agriculture and forestry has been used directly on less toxic media such as iron stone, coal and bauxite wastes and on wastes covered over with deep layers of soil or overburden (Harrison & Hester, 1994). Agricultural crops or livestock or woodland and scrub species are established using conventional or specialized techniques (Giammar, 1997). In practice, it is the combinations of the above approaches based on site-specific considerations that produce the final re-vegetation strategy (Harrison & Hester, 1994). An extension to the above philosophies and their combination, is the "ecological approach" which places emphasis on the importance of establishing biological processes such as nitrogen fixation, decomposition, nutrient cycling and retention and important biotic interactions (*e.g.* pollination) (Harrison & Hester, 1994). The above are some of the issues that indicate proper ecosystem functioning, which is as important as the careful selection of plant species in providing the primary vegetation structure (Harrison & Hester, 1994). Whether the reclamation goals are to restore the original natural ecosystem or to produce an acceptable alternative, ecological principles should underlie all good reclamation schemes (Schab & Postma, 2002).

## 5.3. RE-VEGETATION TECHNIQUES AND LANDUSE

This section deals with the different re-vegetation techniques applicable to specific landuse. Various techniques have been developed to suit particular waste problems, ranging from cultivation with conventional agricultural machinery followed by fertilization and direct seeding for innocuous wastes, to specialist procedures such as placement of a barrier layer or deep coverings of non-toxic materials for very toxic sites (Anon, 1998a). However, many factors have to be considered in the choice of plant materials, and their method of establishment, in particular the nature of the spoil, the prevailing climate and the eventual landuse (Rainbow, 1987). Identification of the problems preventing plant growth coupled with careful selection of species and appropriate long-term management is the basis of successful re-vegetation (Rainbow, 1987). Details of each re-vegetation technique (presented by Rainbow, 1987) are discussed below.

### 5.3.1. Direct Seeding

*5.3.1.1. Normal Species*

Unfortunately, straightforward direct seeding with conventional species and fertilizers is often unsuccessful as a re-vegetation measure, at least an older mine tailings, because of the toxic residual levels of metals that are often associated with high acidity levels (Juwarkar & Malhorta, 1991). Under these circumstances grass and other seedlings persist for only a few weeks (Juwarkar & Malhorta, 1991); however, the procedure remains an attractive option in principle, because direct seeding is cheaper than any other method (Baxter & Wicomb, 2000). In situations where the waste contains little residual metal, or where the metal is not available to plants, normal species can be established directly with the assistance of fertilizer (Bradshaw, 1997). The long-term growth of vegetation depends on an adequate supply of nitrogen, legumes such as white cover or bird-foot trefoil (*Lotus corniculatus*) are an important component of the seed mixture, since they have the capacity to supply nitrogen B fixation of atmospheric sources (Parrota & Knowles, 2000). Trees with rapid growth such as Black Locust (*Robinia pseudoacacia*) can be effective in visual screen plantations for tailings ponds, waste heaps and mine buildings (Toy & Griffith, 2001).

*5.3.1.2. Competition*

Species that grow favourably with other components of a seed mixture should be chosen; for example, establishment of young trees in lush ground cover vegetation may be adversely affected by competition (Robbins, 1996).

*5.3.1.3. Availability*

Species that are available commercially should be selected for planting (Rainbow, 1987). If companies can foresee requirements and order from reputable commercial nurseries giving at least a year's notice, unusual requirements can often be met (Gaunt & Bliss, 1993). For full reinstatement of a diverse native flora, a company should consider establishing its own nursery facilities (Rainbow, 1987).

## 5.4. SURFACE IMPROVEMENT AND COVERING SYSTEMS

In terms of lapsing, cancellation and cessation of the mining operations the surface area should be improved and properly covered to provide a base for plant growth (South Africa, 2002). The method of selection for improving plant growth conditions should be based on (International Committee for Coal Research, 2000):

- alleviating toxicity and acidity,
- augmenting supplies of essential plant nutrients,

- improving the physical properties, and
- achieving maximum benefit from the materials available on site or nearby.

Fertilizer application to tailings is always necessary and use of organic matter is advisable if it can be obtain locally (Griffith *et al.,* 1996). There should be correction of acidity or alkalinity, because a wider range of plants can then be established, while toxicity is alleviated and the availability of nutrients for plants is increased (Giammar, 1997). The principle behind the addition of materials to tailings or covering of a surface is to dilute or avoid toxicity problems rather than counter them by direct seeding of tolerant populations (Marcus, 1997). The covering of mine waste to isolate it from the establishing vegetation is a common approach to reclamation and can succeed if a suitable depth of material can be introduced into which the chosen vegetation can root and develop satisfactorily (Moffat, 2001). Usually the cover material is topsoil, subsoil, or overburden (Chamber of Mines, 1999). It is rarely feasible for economic reasons, to provide depths of cover greater than 300 mm, and in the case of some modern tailings the load bearing capacity precludes the use of most forms of civil engineering equipment required to apply the cover (U.S. Bureau of Mines, 2002). On wastes of low to medium toxicity, covering layers can provide a cheap method of improvement, whilst very toxic materials require barrier layers or isolating materials between the wastes and growing medium to reduce upward movement of metals. In some cases, especially where toxicity is marginal, simple dilution of the waste with innocuous material may suffice (Nichols & Gardner, 1998).

## 5.5. DILUTION

Dilution is one of the most vital approaches used for preparation of re-vegetation to improve the soil capability as a medium for plant growth. This next section outlines the dilution method.

The simplest approach to re-vegetation using amendments is to incorporate suitable material into the mine waste surface on the principle of diluting the influence of the residual metal values below phytotoxic thresholds (Merryweather, 1993). Organic matter in particular is used in dilution, because it has important beneficial effects both on the physical characteristics and the nutrient status of mine wastes (Nichols & Gardner, 1998). Organic material increases the water and nutrient holding capacity, improves surface stability, aeration and water penetration by alteration of the soil structure, whilst decreasing surface run-off and improving the seed bed (Juwarkar *et al.,* 1993). In addition, mine discard can be temporarily complex by organic material that binds them in an innocuous form until natural decay of the organic matrix causes remobilization (Juwarkar *et al.*, 1993). Amendments such as farmyard or poultry manure or sewage sludge are usually incorporated into the surface to 150 mm depth by dicing (Parrota & Knowles, 2000). The aim is to achieve about 3 – 6% organic matter content, which is a level expected in normal soils (Parrota & Knowles, 2000). Modern high analysis, compound fertilizers are used in association with the dilution, and cover approaches to re-vegetation (Anon, 1998b). Compound fertilizers are formulated from compatible chemicals and are easy and clean to handle whilst occupying less storage and transport space than the more bulky organic sources of nutrients (Anon, 1998b).

Compound fertilizers are available to cover most needs (*e.g.* NPK fertilizer 17.17.17 which supplies 17% N, 17% $P_2O_5$ and 17% $K_2O$ by weight) (Cook, 1990). Slow release commercial fertilizers, which release their nutrients in a time graded pattern over months and even years, are more expensive but can produce good results and reduce labour costs (Cook, 1990). Coal, lead–zinc mine tailings in the Peak District National Park in the UK, represent a successful example of the dilution approach to reclamation (United Kingdom, 1989). Another recommended method is hydro-seeding technique, which could be used to residual levels mine discard that is not toxic in order to establish a commercial grass legume seed mix, with the use of air dried, digested sewage sludge, and phosphate fertilizer applied directly to the dewatered tailings surface (Fox, 1984). In many cases, the establishment of grassland together with subsequent planting of trees and shrubs has proved to be very successful and also led to colonization by wildlife (Coetzee, 1998). Surface leaching using overhead sprinkler system as the basis for dilution of acidity has been used successfully along the Witwatersrand near Johannesburg for controlling acid-sulphate levels in the surface layers of gold mine tailings (Coetzee, 1998). Regular mist-spraying regulates the acidity in surface layers at a sufficiently low level to permit the establishment of grasses and legumes after treatment of tailings with lime and fertilizer (Chamber of Mines, 1996).

## 5.6. SIMPLE COVERINGS

Soil or surface cover has been extensively used in many areas for re-vegetation schemes to avoid toxicity and to improve the texture and stability of waste surfaces so that vegetation can be established (Gardner *et al.,* 1991). The simple covering approach has worked well in many areas but failures have also resulted mainly because of (Gardner *et al.,* 1991):

- the lack of penetration of roots into the underlying material leading to poor binding at the soil/waste interface;
- contamination of the covering through upward migration and accumulation of toxic metals, salts and acidity; and

- penetration of plant roots into toxic material beneath, with subsequent regression of the vegetation.

Experience suggests that the minimum depth of such surface coverings should be 300 mm; any thing less than that could lead to erosion of the coverings (Bradshaw, 1987).

### 5.7. BARRIER OR ISOLATING LAYERS

Barriers or isolating layers are used in mining of coal minerals and if properly implemented, they prevent self-heating or spontaneous combustion. Details of barrier or isolating layer method are extensively outlined below.

The use of barrier layers, although less common than the simpler methods, because of higher costs, are currently popular for wastes that present a particular hazard to local communities through toxic pollution, and also where there is a pressing need to develop a specific landuse (*e.g.* sports fields, grazing land), or where vegetative stabilization cannot otherwise be considered due to extremes of toxicity and acidity (Berger, 1990). If simple covering layers such as soil are used on toxic waste, then even with deep layers (>300mm) upward migration of contaminants may in time cause regression of vegetation (Cochrane, 2002). In the above cases, it is necessary to use barrier layers of material designed to inhibit the upward movement of solutes (Berger, 1990). The main requirement is that the barrier layer should disrupt the capillary water columns established within the waste (Alcoa World Australia, 2001). Therefore, the layer should be at least 300mm deep, and should consist of a course-textured material such as screened gravel with no fines, rock waste or coarse non-toxic mine spoil (Hoffman, 1997). The approach has been used and proved to be successful at the copper tailings dam of the old Avoca mine in the Republic of Ireland (Harrison & Hester, 1994). A tailings dam was subject to serious problems before the enactment of a re-vegetation scheme (Harrison & Hester, 1994). Erosion became so serious that direct seeding using tolerant seed presented too great a risk in view of the relative slowness of sward establishment by this method (Harrison & Hester, 1994). Accordingly, a two layered cover approach was adopted in which a layer of shale, 200-300mm deep, was placed on the tailings surface to isolate the material and then overlaid with a skin of 75-100mm of topsoil and subsoil to provide the supportive medium cover vegetation (Harrison & Hester, 1994).

Following preparation, the surface was treated with conventional limestone and fertilizers before being sown with a traditional agricultural seed mixture (Harrison & Hester, 1994). With careful management, the results were outstanding in the first two years

(Harrison & Hester, 1994). A crop of hay was taken from the reclaimed surface in the summer following the year of reclamation (Harrison & Hester, 1994). The quality of the product was such that there were no constraints upon feeding the product to livestock (Harrison & Hester, 1994). The grass surface now supports a wide range of herbaceous species and is now carrying complement of wild life (Harrison & Hester, 1994).

### 5.8. RE-VEGETATION OF TAILINGS AND WASTE ROCK DEPOSIT

Tailings and waste rock deposits pose dangers to structures, animals and human beings and have not all been re-vegetated to acceptable standards; hence, in this section re-vegetation processes for tailings and waste rock deposit will be discussed in detail (Voogd, 2001).

During the operating life of the mine, deposited tailings are normally largely covered by the supernatant mill effluents leaving only the beaches exposed (Tacey, 1979). It is important to minimize wind erosion that can become a serious problem where prolonged dry seasons are encountered (Krige, 1993a). At "close out" or cessation of active operations, it is now usual for regulations to require a permanent system for the management of tailings and waste-rock areas so that they are not a health hazard to their human beings or animals, nuisance is minimized and continued contamination of water courses does not occur (Robbins, 1996). Improvement of aesthetics should be a significant objective; flat sandy areas can be visually obstructive in wooded or mountainous terrain (Street, 1986). Tailings contain major proportions of slimes; the eventual total "dry out" process can be very prolonged and can be accelerated by transpiration from suitable tree plantations (Bradshaw, 1997). When tailings have adequately dried, it is possible to establish vegetation on barren and hostile substrate using techniques that have developed rapidly over the last 10-15 years (Bradshaw, 1997). Control of pH by heavy liming is usually essential, followed by the application of plant nutrients such as nitrogen and phosphorus (Baxter & Wicomb, 2000). Grasses, and other vegetation, indigenous to an area, are often the most promising candidates for successful re-vegetation (Baxter & Wicomb, 2000). Once a limited natural humus cover has been established, legumes can also be incorporated (Gardner *et al*, 1991). Where tailings or waste-rock is highly pyretic, re-vegetation is more difficult, due to the generation of acid (Bradshaw, 1987). Areas can be top soiled before re-seeding but such a procedure is usually inordinately expensive (Bradshaw, 1997).

### 5.9. OPEN PIT MINING

Open pit mining is a mining operation whereby minerals are extracted from the surface of the earth not underground. The open pit mining can be rehabilitated, depending on the weather and hydrology of the area; it may be possible to allow the pit to fill with water, provided it is acceptable for recreational or fishing purposes and does not contaminate local surface or ground water (Rainbow, 1987).

### 5.10. MANAGEMENT AND AFTERCARE

Management and post mine closure aftercare involves the neutralisation of the toxic substances and proper monitoring system of the rehabilitate lands (South Africa, 2002). Details of management and aftercare are explained in this section. Where toxic wastes are reclaimed, regression of a well-established sward could occur (Mining Magazine, 1995). Regression may be due to one or more of the following (Mining Magazine, 1995):

- weathering of pyritic wastes producing acidity, which in turn alters the variability of plant nutrients and toxic metals,
- gradual decomposition of organic amendments releasing metals previously held in stable organic complexes,
- depletion of nutrients required for growth,
- extreme weather conditions, and
- upward migration of acidity, heavy metals, or salts into surface layers of amendments.

It is vital that long-term management should be considered as an integral part of any reclamation scheme and should be planned at an early stage (South Africa, 2001a). However, the programme of long-term management depends upon the species sown and the landuse objective (Toy & Griffith, 2001). Re-fertilization and management of a legume component, cutting/grazing, pruning, and tying of trees, and fencing maintenance, may all be regarded as components of a management programme for a reclamation site (van Gessel, 1993). "*Rome was not built in a day*", and neither can a self-sustaining soil/plant ecosystem be rebuilt in a single act (Laurence, 2001). The process of restoring the chemical, physical, and biological functions of a soil takes time (Laurence, 2001); if the soil is being made from raw waste the restoration will obviously take a very long time (Street, 1986). Even if a soil is removed from an area and replaced almost immediately, it will take time to recover (Street, 1986). The vegetation that will have been completely destroyed will take several years to be properly restored, unless the land is being used for annual crops (Bradshaw, 1987).

Aftercare will be problematic in all land restoration, and failure to realize that, has been the cause of failure of very many reclamation schemes (South Africa, 2001a). Less successful reclamation requires greatest attention. Sometimes a structure will be imperfect

(Toy & Griffith, 2001). Imperfect structure can be restored by cultivation and the growth of plants (Toy & Griffith, 2001); it will, however, take several years for the plants to exert their maximum effect in breaking up soil aggregations by root growth and contributing sufficient organic matter to lighten the material (Laurence, 2001). Until such a situation occurs, the material will need to be treated with care, or it could be damaged (Bradshaw, 1997). A considerable input of nutrients is always necessary (Bradshaw, 1997); this cannot be done in one operation by providing more fertilizers than the plants can take up, so fertilizer may leach away and be wasted (U.S. Bureau of Mines, 2002). The need is moderate input that continues for a number of years (Walde, 1992). Yet, that is often forgotten, and after the initial application no more is provided and this can lead to serious regression of vegetation (Walde, 1992). If aftercare is not given all the money, effort expended on the reclamation can be wasted (Laurence, 2001). Like many other problems aftercare can easily be overcome if the right steps are taken (Laurence, 2001).

## 5.11. PREVENTION AND MANAGEMENT OF SELF-HEATING (FIRES) IN COAL MINING

Prevention and management of self-heating processes are outlined in this section; the processes are only applicable to coal mining. In open cut or surface mining, large volumes of coal and carbonaceous material are exposed to oxygen in air (U.S. Bureau of Mines, 2002). Once exposed, the materials oxidize and liberate heat. If the heat is not dissipated sufficiently rapidly, the temperature rises; this drives the oxidation and heat generation process at a faster rate and if unchecked, spontaneous combustion may result (Cochrane, 2002). The consequences of spontaneous combustion in spoil piles may be significant (Mining Magazine, 1995). For example, open fires and smouldering combustion can give rise to toxic fumes such as carbon monoxide, carbon dioxide, nitrogen dioxide, and sulphur dioxide, as well as the 'tarry' emission products associated with incomplete coal combustion. Further consequences arise from the danger of fire spreading to surrounding land, the destabilization of the landform with possible subsidence, landslides, and the death of vegetation in the vicinity of the 'hot' spoil (Mining Magazine, 1995). The final landform design provides the fundamental solution in preventing self-heating in coal mine spoil. Planning spoil dumps and the ongoing management of spoil prevents outbreaks of spontaneous combustion (Shankar & Kapoor, 1993)

### 5.11.1. Best Practice Principles

The "Best Practice Principles" applied to the prevention of self-ignited fires in mines include (Mining Magazine, 1995):

- defining all fuel sources, ensuring the correct placement of carbonaceous materials;
- minimizing the quantity of fuel (carbonaceous materials) going to spoil;
- reducing oxygen pathways in spoil piles;
- avoiding dumping carbonaceous or hot materials over dump batters; and
- using a "prevention is better than cure" principle.

### 5.11.2. Best Methods for Control

The self-heating management practices for dragline and truck-shovel operations, truck-dumping practices that can be effective in prevention of self heating include (Environment Australia, 1998):

- controlled placement of carbonaceous overburden and partings with inert "pockets";
- limiting lift height to a maximum of 15 m;
- covering all final surfaces with a 5 m layer of inert material;
- compacting final surfaces, as well as intermediate surfaces wherever possible;
- spreading out and track rolling carbonaceous material to prevent heat build-up and oxygen ingress;
- sealing hot spoil with a cover of clay as an effective technique to control heating (for this to succeed, careful planning, execution and commitment to seal maintenance over many years are keys to successfully reducing soil temperatures below acceptable levels; *i.e.* below 70$^{o}$C); and
- grouting with inert material such as flyash as a potential alternate technique for fire control (the objection is exclude air from the fire by filling the voids between the spoil particles, while the advantage of this method over sealing is that it creates an *in situ* barrier to air transport rather than a potentially unstable surface barrier).

### 5.11.3. Guiding Management and Fire Control Principles

The US Bureau of Mines (2002) suggested the following actions as principles for controlling fires:

- close oxygen pathways into spoil piles by surface capping or bulk void reduction;
- maintain surface seals;
- if it is not possible or practical to seal an area, spreading the material will prevent heat build-up;

- promote cooling by encouraging rainwater ponding; and
- early intervention is the key to prevent longer-term problems.

#### 5.11.4. Top Soil Grafting Averts Self Heating

The above methods were applied in the Leigh Creek Coalfield mine; one of the largest open-cut operations in Australia (Barker *et al.,* 1995). The site covers area of 70 sq km and has produced 2.6 to 2.8 million tones per annum of sub-bituminous hard brown coal. Site operators controlled self-heating at Leigh Creek by compacting the final surface and by placing freshly stripped topsoil over the compacted material (Alcoa World Alumina Australia, 2001). Observations indicate that method has prevented self-heating. The topsoil was stripped from the areas to be mined and placed immediately over the compacted overburden material. The “top soil grafting” method has also led to very early natural regeneration of suitable native plants (Barker *et al.,* 1995).

# CHAPTER 6: CONCLUSION

It can be concluded that, if the mining industry is to contribute effectively to future sustainable development, it must develop and consistently apply sound environmental management practices worldwide (Moffat, 2001). As a matter of urgency, mining industries should minimize environmental impacts on and off-site during the operational mining phase. Mining industries should extract and use resources efficiently and to encourage the efficient processing and use of their products (The World Commission for Environment and Development, 1987). While minerals are a non-renewable resource, in many cases they can be efficiently reused and recycled. Consistent with sustainable development principles, mining operations should be intended as a transient landuse (Nichols & Gardner, 1991). This means that after mining, the condition of the land should be reclaimed so that its value is similar to or greater than it was before disturbance.

There are many examples in which mined land has been effectively rehabilitated to agriculture, forestry, and nature conservation or urban or industrial landuses (Laurence, 2001). A typical example in this regard is the Ermelo Mines in South Africa. In some of these instances the pre-mining landuse was reclaimed, while in others the landuse was changed. Some of the changed landuses were carefully planned and implemented, while others have evolved, sometimes after the land has undergone a lengthy period as abandoned or waste land (Moffat, 2001). Therefore, mine reclamation (also referred as rehabilitation) should be the process of converting mined land to its future valuable use; not a process of burying wastes, smoothing out the landscape and applying a green mantle of relatively valueless vegetation (Bradshaw, 1997).

The severity of the environmental problems created by mining activities and colliery waste depends on the characteristics of the waste materials and the situation of the site (Anon, 1998a). As mentioned above, environmental problems vary from physical visual intrusion to land instability, pollution of run-off, land sterilization, dust blow, spontaneous combustion, erosion on steep slopes, and improper drainage, amongst others. The formulation of solutions to most of the above-mentioned problems would depend on proper analyses of the data from the initial choice of dumpsite, stockpiling location, site screening technique, material placement method, and proper landscaping (Hoffman, 1997). Few would dispute that the damage done to the earth due to mining is reprehensible and should be corrected. Certainly, as a society and as ordinary people in our own rights we must make heroic efforts at this time in our history to protect all remaining relatively pristine resources to prevent any further loss of land and species (Hoffman, 1997).

Threatened and endangered species should unquestionably not have to wait any longer for effective protection (Laurence, 2001). Rehabilitation should be a moral obligation. It is hardly ever practical to wait for nature to take its course, and certain sorts of derelict land have particular problems, which time and nature will not heal. On the other hand, it is worth noting that with modern mining methods, increased environmental awareness and regulations, and the requirement for post-mining rehabilitation have reduced the incidences of post-closure environmental damage due to mining (South Africa, 2001a). However, environmental and physical problems within the earlier abandoned mine lands are, in many cases, not yet fully developed and the problems presently visible at the older sites are likely to increase in magnitude (Owens & Cowell*,* 1994). Moreover, unless action is taken to rehabilitate sites or mitigate their impacts, they will continue to have a significant effect upon the natural environment. As human populations grow and the pressure for land for habitation, agriculture and industry increases, abandoned mines will obviously represent a continued safety risk to inhabitants and an ever more significant stumbling block to the social and commercial developments of mining regions (Parrota & Knowles*,* 2000). The severance and the extent of surface subsidence and underground fires at the Delagoa Bay mine (Mpumalanga) site is a typical example (see Sowetan, 2001). Similar problems are evident in other old mines in the Witbank and Ermelo areas, and in isolated instances elsewhere in the South African coal fields (South Africa, 2001b). A large number of old mines remain in the portfolio of current mining houses, which retain responsibility for their management and liability for final rehabilitation and closure. The previously mentioned concerns are legitimate, because in a number of cases, the mining or holding companies responsible for derelict and onerous mines have ceased to exist and in many instances the owners of the mines cannot be traced, and the responsibility for their rehabilitation becomes the responsibility of the State (South Africa, 2001a). The prospects for rehabilitation in the near future of derelict mined land held by the state are very uncertain (Chamber of Mines, 1996). The reclamation checklists used by the DME are also a cause of great concern and have some notable shortcomings (Voogd, 2001). More often than not, the use of checklists has been criticized; however, checklists do provide a valuable summary of expert knowledge in an easily accessible format.

The study found that checklists, in particular the checklists used by the DME, needed to be improved. While the DME checklist provided a relatively comprehensive list of the baseline information required from the initial site survey, it failed to highlight the need to interpret that information and link it to the development of the three components (landscaping, re-vegetation, and monitoring and aftercare) of the rehabilitation programme

(Voogd, 2001). As a result, the majority of rehabilitation reports merely describe the local conditions without attempting to indicate how they would influence the implementation of the rehabilitation programme (van Gessel, 1993). It appears that the majority of rehabilitation reports drawn up in South Africa are simply approached as legal requirements and are not documents aimed at providing achievable, long-term solutions to the disturbances caused by mining (Schab & Postma, 2002). Unless rehabilitation reports can function as effective working documents, the commitment to rehabilitation will remain doubtful (Viljoen, 2002). The reports/guidelines should be seen as legal documents that will bind the mining operator to follow the outlined procedures. Mining operators should be held accountable if rehabilitation is not carried out according to the respective reports (South Africa, 2001a). Both the operator and the authorities should undertake monitoring and after-care (Chamber of Mines, 1999). At present, it seems that the first time the authorities see the reports is also the last time they concern themselves with rehabilitation aspects. On the other hand, it is worth noting that the regulations that were incorporated in the Mines and Works Act in 1980 introduced, for the first time, an environmental dimension to the work of the government mining engineer (Voogd, 2001).

Whereas in the past, a government mining engineer had been concerned solely with matters relating directly to the operation of mines, the person now has to consider the safety, health and welfare of workers and the public. With the new regulations, a number of specialized tasks such as environmental impact assessments, re-vegetation procedures, soil analyses, aesthetic and visual impact analyses were introduced (Voogd, 2001). Government mining engineers are to a certain extent, not suitably qualified to determine whether a report is a good one or not. The impression is that if the report says the "right" things (mentions climate, soils, overburden, stockpiling, re-vegetation, *etc*.), it is passed (Voogd, 2001). In addition, a government mining engineer is also unlikely to be suitably qualified to comment on the progress of a rehabilitation project; this kind of lack of commitment often promotes the so-called "walk-away" or "mediocrity" options, which are regrettably the reality of many mining sites in South Africa (Chamber of Mines, 1999). Rehabilitation of mines should go hand in hand with the growth of the mines. Governments, mining companies, and the minerals industries should in a nutshell and as a minimum (Cochrane, 2002):

- Recognize environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management systems. These should include early and comprehensive environmental impact assessments, pollution control and other preventive and mitigating measures, monitoring and auditing activities, and emergency response procedures.

- Establish environmental accountability in the mining industry and the government at the highest management and policy-making levels.
- Encourage employees at all levels to recognize their responsibility for environmental management, ensure adequate resources, staff, and requisite training should be made available to implement environmental plans, ensure the participation and dialogue with the affected community and other directly interested parties on the environmental aspects of all phases of mining activities.
- Adopt the best practices to minimize environmental degradation, notably in the absence of specific environmental regulations.
- Adopt environmentally sound technologies in all phases of mining activities and increase the emphasis on the transfer of appropriate technologies which mitigate environmental impacts, including those from small-scale mining operations.
- Seek to provide additional funds and innovative financial arrangements to improve environmental performance of existing mining operations.
- Adopt risk analysis and risk management in the development of regulation and in the design, operation, and decommissioning of mining activities including the handling and disposal of hazardous mining and other wastes.
- Reinforce the infrastructure, information systems, service, training and skills in environmental management in relation to mining activities.
- Review environmental regulations that act as unnecessary barriers to trade and investment.
- Evaluate and adopt wherever appropriate, economic and administrative instruments such as tax-incentive policies, and emission-rights trading to encourage the reduction of pollutant emissions and the introduction of innovative technology.

Notwithstanding the progress that has already been made towards finding solutions to the problems associated with historic mined land in South Africa, a concerted and sustained effort involving the State and the mining industry is necessary to ensure that future developmental potential of mined land is realized (Chamber of Mines, 1999). Reclamation to achieve environmental improvement is also essential in order to attract investors and provide an attractive setting for development (South Africa, 2001a). To create big holes in the ground and mountains of waste is no longer a fashionable activity. There must be no more of digging a hole in the ground, making money, declaring bankruptcy, running away and leaving the mess behind (Anon, 1998a). The time has come for us all to send a clear message to the world that South Africa is not a haven for glory hunting prospectors and diggers with one arm and a wheelbarrow (Voogd, 2001). But where such insensitivity towards the environment occurs, they (diggers) too are obliged by the law to lift a shovel for the environment. The new rule of the mining game should be "Anyone who scratches the surface to make money will be made to roll the rocks back" (Krige, 1993a:89). Tourists like to visit historical mine sites with "*son et lumiere*" and wax figures of historical miners, but they do not journey to valleys and mountains where real mines spew out dirt and smoke (Walde, 1992: 33). In other countries (*e.g.* some in Europe), it is not even enough to return a mined out area to an acceptable aesthetic appearance; it must be also capable of supporting vegetation (Mining Magazine, 1995). Yes, derelict land can be transformed into something for people to enjoy, now and in the future; ***It is time to win back the land.***

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