Post-mining land use opportunities in developing countries

D. Limpitlaw* and A. Briel†
**Centre for Sustainability in Mining and Industry,*
University of the Witwatersrand
†Knight Piésold (Pty) Ltd, South Africa

The origins of mine closure practice have influenced the way in which it is implemented by companies and regulators. Mine closure practices essentially started developing in the 1970s in countries with advanced economies and mature mining industries. In these settings, the emphasis was justifiably placed on restoration of the landscape and an attempt was made to return to the 'natural' pre-mining land cover. These practices continued to evolve and incorporated socio-economic and cultural aspects, especially after the Brundtland Report in 1987 and the subsequent Earth Summit in 1992.

Today mining is increasingly occurring in remote parts of developing countries where there may be significant need for infrastructure such as roads, clinics, and schools. The costs of returning land to low (economic) value pre-mining land use may be far greater than establishing a viable post-mining land use. This viable land use may potentially add value to the community and take pressure off sites for greenfield development elsewhere; in addition, natural resource limitations (such as topsoil availability) may limit the degree to which the historical land cover can be re-established. Establishing post-mining land uses may aid in mitigating the loss of employment that is inevitable when mines close.

Stakeholder participation in establishing post-mining land cover and land use options is critical for long term success. Similarly, third parties must be identified to support the development of the post-mining land use.

This paper draws on the experience of the authors in several developing countries and presents a case for maximizing re-use of mining infrastructure. It does not advocate the adoption of poor rehabilitation standards nor or the wholesale destruction of land capability, but does advise leaving key infrastructure in place for post-mining use that may support sustainable development.

Introduction

Mine closure is the process of transforming an active mine into a set of safe and stable landforms that are non-polluting and provide habitat and ecosystem services and/or support economic activities by the new land users. These activities and habitats may be different from those historically present on the site.

Mining is different to most other land uses in that it is temporary and ceases when the orebody is exhausted. Mining may persist in one location for hundreds of years, but modern mines are typically of short duration and many close within a decade of construction. Historically, worked-out mines were simply abandoned, leaving behind sterilized landscapes with limited economic potential that continued to degrade their surroundings through air and water pollution. Today, society expects mining land to be transferred to new productive uses, the pre-mining land use, or to conservation use once mining ceases.

Restoration, a term frequently used in North America, involves attempting to return an affected landscape to its pre-mining state, use, and condition – recreating the original topography and re-establishing previous land capability together with groundwater patterns and faunal/floral assemblages (Bowman and Baker, 1998; Coppin, 2013). Re-establishing pre-existing ecosystems may not be possible in highly degraded mining landscapes. The landscape surrounding the mine site is also commonly subject to secondary development or a population influx (especially in developing countries). These surrounding areas may be so degraded on mine closure that there is little value in conserving the mine site in isolation.

Reclamation, a term often applied to derelict and abandoned land, requires returning disturbed land to a state where pre-disturbance conditions are not restored but a different condition is established that is appropriate to surrounding land uses and conditions (Bowman and Baker, 1998). The post-reclamation use is not necessarily related to the pre-disturbance use. Rehabilitation refers to the transformation of land from its original condition, through mining, to a new and beneficial condition (Coppin, 2013). This process results in the return of land to a stable condition, capable of supporting permanent use as directed by a mine plan. This new, rehabilitated state must not contribute to environmental deterioration and must be consistent with surrounding aesthetic values, but can be significantly different to the historical state of the land. Rehabilitation allows alternative land-use opportunities.

Mine closure practice

Modern mine closure planning and practice preferentially follows and applies established and tested templates for closure that are implicitly based on the complete removal of mining infrastructure and the restoration of the pre-mining landscape. This approach is seen as lower risk, even in poor under-developed and populous areas where there is an infrastructure deficit. This perception has a lot to do with the level of control that can be exercised by a company over the closure process – lower levels of control are associated with multi-stakeholder planning where working infrastructure is handed over to a third party on completion of the closure process.

The origins of mine closure practice have also influenced the way in which it is implemented by companies and regulators. Mine closure practices essentially started developing in the late 1960s and early 1970s in countries with advanced economies and mature mining industries. For example, reclamation planning in Canada was entrenched in law in 1969 when British Columbia became one of the first mining jurisdictions to introduce mine reclamation legislation (Bowman and Baker, 1998). In these settings, the emphasis was justifiably placed on restoration of the landscape and an attempt was made to return to the 'natural' pre-mining land cover. These practices continued to evolve and incorporated socio-economic and cultural aspects, especially after the Brundtland Report in 1987 and the subsequent Earth Summit in 1992. In many African countries, as well as in other developing countries, this traditional approach is sub-optimal and reduces the ultimate contribution of a mine to long-term sustainability.

Regulatory authorities have traditionally been reluctant to grant closure. Mining companies are thus more likely to select closure land uses that offer the greatest likelihood of relinquishment, rather than the most sustainable land end-use.

Current closure practice

In the past, some rehabilitation of mined land was driven more by public relations considerations than science. Ziemkiewicz (1987, in Bowman and Baker, 1998), for instance, noted that the intensity of reclamation activity in the 1980s was directly related to the public desire to produce alternative land uses from extremely disturbed landscapes. Another example is provided by the State of Florida in the USA. For the first five years after the adoption of the reclamation requirements in the Florida Administrative Code in 1975, the emphasis was placed on hiding the evidence of mining activity (Brown, 2005). Consequently, companies were required to level spoil piles and plant trees. State regulation then evolved to include success criteria such as 'no visible evidence of erosion' and 'survival of 400 trees per acre'.

Today, closure planning is a science-driven activity dominated by planning priorities in OECD countries (especially the USA, Canada, and Australia). These priorities are most commonly focused on the restoration of pre-mining landscapes. Brown (2005) states that restoration efforts (with reference to phosphate mining in Florida) should be focused on re-establishing pre-disturbance ecosystem function. This assertion is supported by Wiegleb *et al.* (2013) who report that in the USA, rehabilitation results have been assessed relative to a natural or reference state that is based on a hypothetical, historically defined state, unaltered by human activity.

Focus on landscape restoration

In Canada, as in Australia, mining operations are frequently located in remote areas, far from settled communities. In such cases, it is appropriate to completely remove infrastructure as there is little need for mining infrastructure post-closure. Bowman and Baker (1998) report that for the Northwest Territories Diamonds Project, all structures were to be cleared and removed, portals sealed, obtrusive landforms contoured to match surrounding topography, and natural drainage patterns restored. Managed revegetation programmes were to take place in areas of high erosion potential, but the rest of the site would be allowed to revegetate naturally.

Another typically 'developed country' approach was adopted for the Mount Polly open pit copper and gold mine in British Columbia. Here the primary objective of the reclamation plan was to return all mine-disturbed land to an equivalent level of capability to that which existed prior to mining (on a property-wide basis). This was to be achieved by preserving water quality, stabilizing engineered structures (such as waste rock dumps, tailings storage facilities, and pits), the removal of roads and equipment, integration of disturbed land into the landscape, and the establishment of self-sustaining vegetation cover (Bowman and Baker, 1998).

Stakeholders in these countries may also prefer conservation-based post-mining land uses to ongoing economic activity. Surveys by the bauxite miner, Alcoa, found that the general public near their operations in Western Australia favoured restoration of native jarrah forests over the provision of recreational areas such as lakes and grassed picnic sites (Burton *et al*., 2012). These sites were previously opencast bauxite mines. One of Alcoa's stated rehabilitation objectives was to increase the ecological significance of the rehabilitated site by including all plant species found in an un-mined forest and to re-introduce threatened fauna to the site (Burton *et al*., 2012). This approach is summarized by the Society for Ecological Restoration International, who state that site restoration attempts to return an ecosystem to its historic trajectory, using historic conditions as the starting point for restoration design (SER, 2004).

North American practice stresses the site specificity of reclamation with emphasis on the testing of vegetative coverage on various surface disturbances (Bowman and Baker, 1998; Wiegleb *et al*., 2013), the pre-contouring of areas to a planned and stable topography, public safety/hazard issues, and habitat regeneration. They also emphasize how the reclamation relates to wider systems that surround disturbed areas and how reclamation relates to traditional land uses prior to mining. In the late 1990s, the question of reclamation and its role in community development, including the transfer of the site from the company to the previous or future owners, was missing in case studies examined by Bowman and Baker (1998).

Developing countries and rehabilitation

In developing countries, in instances where no definite or beneficial land use is identified, areas restored to 'wilderness areas' or 'unused conservation areas' may attract undesirable post-closure land uses. Examples of these include reclaimed tailings footprint sites in the East Rand and West Rand of Gauteng, where informal settlements have established as land has become available. These areas are not suitable for housing developments due to the risks posed by residual tailings material.

In South Africa, the area between Roodeplaat and KwaMhlanga is considered a hotspot for sand mining. A common post-closure land use for mined-out sand mines is to restore the area to its pre-mining land use, namely low-intensity grazing. The post-mining topography and soil profile is very difficult to restore and these mines are often located close to watercourses, making erosion a significant problem. When livestock are added to the sparsely vegetated 'rehabilitated' landscape, erosion gullies are quick to set in and the landscape degrades further. Consultation with stakeholders such as surrounding landowners, conservation, and tourism authorities would likely be able to identify more sustainable closure land use options.

Mined-out quarries have successfully been used as adventure tourism facilities. These land uses have a high commercial value and offer employment opportunities, as opposed to derelict quarries. An example of such a facility is Bass Lake near Meyerton in Gauteng.

There is general acceptance that reclamation should not be a final set of on-site activities, but should rather consist of a progressive sequence of interventions, starting with the earliest stages of exploration and planning, integrated into the full life of the mine (Dowd and Slight, 2006; Fourie and Brent, 2006; Finucane, 2008; Limpitlaw and Mitchell, 2013). These actions should, however, not be limited to land form re-establishment and revegetation but should include consideration of the post-mining re-use of infrastructure. For example, at a potash project in the Republic of Congo (Congo-Brazzaville, ROC), the mining company decided to locate processing and staff facilities away from the nearby national park, closer to an existing town which would act as a natural node of development over the course of the mine's life. This development would be more likely to be sustainable post-closure and would also reduce pressure on the park as it would have the effect of drawing people away from the park.

Proposed improvements

The practicality of restoration

Bowman and Baker (1998) questioned whether mine reclamation represented a method of mine closure that minimized environmental degradation or an opportunity to enhance and develop the disturbed land base towards an ecologically productive state.

Returning mined land to a state of 'naturalness' is not only often sub-optimal from a post-mining land use perspective, but may not be possible. The goal for rehabilitation of mined land in Australia is typically to restore the pre-mining land use or ecosystem (Queensland DEHP, 2012, in Doley and Audet, 2013), and it is assumed that the rehabilitation process will ensure that landforms, lithology, and soil will closely resemble conditions of the pre-mining environment. This may, however, not be possible at many mine sites where radical landscape changes have occurred and persistent artificial features introduced (Doley and Audet, 2013). Additionally, restoration of the pre-mining environment potentially limits the opportunities for land uses that may be more socially acceptable and ecologically sound (Doll, 1988 in Bowman and Baker, 1998).

Doley and Audet (2013) stress the need to consider the creation of hybrid ecosystems and novel ecosystems post-mining. The former would be slightly different in form and function to the original ecosystem and would share many attributes with them. The latter would consist of new combinations of physical and biological attributes due to the changed conditions in the post-mining environment. Basically, the work of these authors shows that where biotic and abiotic systems have been significantly and irreversibly changed, the installation of managed ecosystems or novel, unmanaged ecosystems may be achievable and predictable options. This provides opportunities for the incorporation of enhanced land-use value not found within the pre-mining ecosystem. It is critical that all stakeholders (operator, regulator, and the community) are involved in setting and accepting the parameters for decision-making.

The primary goals of rehabilitation identified by Doley and Audet (2013), namely attainment of the highest achievable standards of biological conservation and ecosystem stewardship, are not incompatible with leaving infrastructure behind, especially when the mine site is not considered in isolation but within a broader regional setting. Re-use of mined land for fuel wood production, for instance, may be less ecologically desirable than the re-establishment of the pre-mining, indigenous woodland, but harvesting of fuel wood from a plantation is more desirable than the degradation of adjacent, intact woodland ecosystems.

Doley and Audet (2013) state that meaningful ecosystem recovery may not occur on rehabilitated, highly disturbed mine sites. Instead of focusing on ecosystem development, they argue for the establishment of safe, stable, and non-polluting landforms that support habitat development. They believe that regardless of the final landscape, the post-mining site will always require some intervention. This supports the need for optimizing the value of post-mining land use to ensure that the required management interventions are sustainable.

There is evidence to show that sustainable, multi-functional use of natural and semi-natural landscapes exceeds the gains from their conversion to single purpose land-use types (De Groot, 2005). Natural landscapes commonly provide a multitude of functions and are subject to many possible land uses. Closure planning should attempt to create a post-mining landscape in which multiple land uses are possible so that a level of sustainability more closely approximating that of the pre-mining landscape can be achieved. To approach such improved levels of sustainability, multifunctional post-mining landforms are required.

To maximize the benefit derived from post-mining landforms and to ensure optimal use of resources in the rehabilitation programme, the mine lease should be divided into a number of land use precincts. These precincts are typically determined by the existing land use, current and future surrounding land uses, the nature of the precincts' topography, and the level of disturbance. A closure options analysis exercise is required to identify closure options and select a preferred option for each precinct. The preferred closure option will inform the direction of the closure strategy and closure cost estimate.

Mine closure and social development

Today mining increasingly occurs in remote parts of developing countries where there may be significant need for infrastructure such as roads, clinics, and schools. The costs of returning land to low (economic) value pre-mining land use may be far greater than establishing a viable post-mining land use. This land use may potentially add value to the community and take pressure off sites for greenfield development elsewhere. In addition, establishing post-mining land uses may aid in mitigating the loss of employment that is inevitable when mines close.

Maximizing the post-mining value of mining infrastructure may contribute substantially to post-mining economies. At a gold producer in a small Pacific island state, the mine's sports facilities are considerably better than those in the nearest regional centre. The rugby fields, golf course, and bowling club have enabled teams from the local community to participate at national and international level in these sports. Part of the challenge of closure planning is finding effective ways of maintaining such facilities once they are handed over to the community on closure. Similarly, in a country with a tourism-focused economy, the establishment of heritage tourism sites using old mine buildings and equipment should be possible. Notable successes in heritage tourism were reported at the site of the former Waihi Gold Mine in New Zealand (Thompson, 2011).

At a copper producer in Katanga, southern Democratic Republic of Congo (DRC), the company's accommodation facilities present an opportunity for re-use post-closure as a training and conference venue as they are within an easy drive of Lubumbashi, the provincial capital. The attractiveness of this land use option is reinforced by looking at ways of maximizing use of the mine's power and water reticulation infrastructure. Light industry is already establishing itself on the outskirts of Lubumbashi and by the time the mine closes, it is not unlikely that the site could act as an industrial development incubator.

This approach is already being adopted by some multinational mining companies: in the Mine Closure Toolbox, Anglo American states that exploitation of mineral resources should also contribute to the infrastructure base and provide an economic stimulus for sustainable development in the host region (Anglo American, 2013).

Discussion

The use of mining landscapes (including infrastructure) can improve the contribution of mining to sustainable development, but stakeholder participation in establishing post-mining land cover and land use options is critical for long-term success (Limpitlaw and Hoadley, 2006). Similarly, third parties must be identified to support the development of the post-mining land use. Additional stakeholder participation in the closure planning process is required to ensure that any remaining infrastructure can be effectively used after closure.

Should infrastructure remain post-closure, landscapes must still be stable, non-polluting, and non-hazardous. Environmental liabilities should not be carried over to the post-mining land users and site handover should only occur once all risks are mitigated to acceptable levels.

Where the post-mining land use is different to the original land use, it is inevitable that biodiversity may be impaired or agricultural land may be lost. In such instances offsets may be required to ensure no net loss of biodiversity or agricultural land. These offsets should be established early on in the life of mine to ensure sustainability post-closure.

The post-closure land use must generate or sustain employment opportunities for local communities and/or redundant mine employees. Exploring new approaches to rehabilitation may present an opportunity to integrate disturbed landscapes and the community. This reduces the risks of socio-economic collapse post-closure and supports the notion of a social licence to operate (for mining companies). Re-use of brownfield sites may save greenfield sites elsewhere (which have higher conservation value) from being developed.

Conclusions

Closure planning should commence during the feasibility stage of a mining development project, as closure should be one of the aspects to consider in deciding whether a project should be developed. If a financially viable, sustainable land use cannot be identified at feasibility stage, the developer should be aware of the long-term financial implications if relinquishment is not possible.

Closure consultation with affected communities may be an emotive issue, as a mine is often linked to a large portion of their livelihood. Such consultation is, however, essential in order to identify the most viable land use options or redevelopment opportunities.

The risk-averse approach to closure may not always offer the most sustainable solutions and is not guaranteed to ensure relinquishment. Working with reputable development partners during the life of mine is likely to offer ongoing employment opportunities and an alternative source of livelihood to affected communities upon mine closure.

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The Author

Daniel Limpitlaw, *Principal*, Limpitlaw Consulting

Dr. **Daniel Limpitlaw** is a mining engineer, specialised in the assessment of both direct and indirect impacts of mining on the environment and the surrounding communities. He has experience through the entire mining life cycle on projects across Africa and in several countries further afield.

He works on projects relating to small scale mining, management of mining impacts, and spatial assessment. Daniel consults extensively in the fields of mine environmental management, mine closure, mining-led local economic development and impact assessment.

Daniel was previously the director of the Centre for Sustainability in Mining and Industry at the University of the Witwatersrand and was the technical services manager at Vatukoula Gold Mines Ltd in Fiji. He runs a niche consultancy specialising in analysis of, and solutions to, problems around sustainability in the mining and minerals sector.