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South Africa's challenges pertaining to mine closure — development and implementation of regional mining and closure strategies

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Abstract

Following the World Summit on Sustainable Development in 2002, the South African Department of Minerals and Energy (DME) initiated the "Sustainable Development through Mining" (SDM) programme to assist in the development of a strategic framework for sustainable development in the minerals and mining sector. This initiative supported a variety of projects including a project specifically orientated towards integrated regional mine closure and its implications. This paper focuses on the increasingly challenging environment of changing community expectations, stricter regulatory controls and greater public scrutiny in areas of cumulative, interconnected, or multi-mine, and/or an integrated environmental and socio-economic impact at a regional level. The paper discusses the challenges in the development and implementation of the concept of regional mine closure strategies, as support to further policy and legislative interventions in South Africa, and outlines proposed strategies to address these challenges. Regional closure strategies aim to provide a framework within which mines can develop closure plans that address broader development priorities as well as possible cumulative impacts of a number of mines, taking into consideration socio-economic and environmental issues on a regional basis. A strategic framework was developed for the Witwatersrand gold mining region within which individual mines will be able to plan for mine closure. In order for the strategy to be implemented there are a number of key success factors. These include issues around closure planning, buy-in from stakeholders, trade-offs, stakeholder engagement, setting-up of completion criteria (balanced scorecard for regional mine closure), targeted research and data management. This paper is a follow-up on work reported.

1 Introduction

Mining does, in general, have a substantial impact on the environment, and has unfortunately left South Africa with an enormous economic, social and environmental legacy. The challenges are mainly in areas where mines have an inter-connected and/or an integrated environmental and socio-economic impact. The Republic of South Africa remains one of the world's leading mining and mineral-processing countries. The Witwatersrand Basin holds an estimated 45% of the world's known resources of gold and has contributed 1.4 billion ounces of gold, representing 40% of all gold that has ever been mined throughout world history (Robb and Robb, 1998) (see Figure 1). Witwatersrand Basin operations were mostly deep-level underground mines exploiting gold bearing, shallow dipping reef bodies, which have produced gold over a period of more than 115 years. Despite the decline in production in recent years, the industry remains one of the world's largest gold miners. The extraction of gold from the Witwatersrand gold reefs has been carried out more or less continuously since the 1880s to produce a 100 km elongated mining belt situated south of central Johannesburg, South Africa. Initially the outcropping reefs were exploited at surface but as techniques improved extraction of deeper reserves were targeted. Openings, such as shafts, raises and winzes, excavations etc., were created. A large east-west striking underground mining void soon developed as the gold bearing rocks were removed. As mining continued the in-rush of water became an ever increasing problem, resulting in the dewatering of the overlying dolomitic compartments. For more than a century, the mines of the Witwatersrand have discharged contaminated water into the streams and rivers of the area. The additional water generated by mining and other human activities has led to the formation of a system of large wetlands which perform an important function in the purification of water. As the attention of the various mining houses turned to deeper mining opportunities, scant thought was given, nor required, to rehabilitating the disturbance caused by the efforts of the previous mining attempts. Along with surface collapse, these openings now form a safety risk to inhabitants of encroaching informal settlements. Furthermore the conglomerates of the Witwatersrand Supergroup and underlying Dominium Group contain relatively high percentages of uranium (U). Although gold was the principal commodity of the Central Rand Group (including the Carbon Leader Reef and Middelvlei Reef) of the Witwatersrand Supergroup it is also the most important uranium host rock in South Africa. On the peak of U production in 1980 South Africa was the seventh largest U producer with an output of some 7000 t U (Coetzee et al., 2006) However, as interest dwindled U extraction from gold ore has ceased, resulting in U being discarded on tailings facilities. In recent years concern has been expressed about the concentration of contaminants, particularly metals in the river and wetland systems and questions have been raised about their ability to cope with the pollutant loads (Coetzee et al., 2002). The sediments reduce the metal loads in the water draining the Witwatersrand, although this hazard of polluted sediments now remain for a number of kilometres downstream of the pollution sources.

Earth tremors and rockbursts were a cause of concern to mining communities in the Witwatersrand region of South Africa as early as the first decade of the 20th century (Durrheim et al., 2006). In the goldfields of South Africa, there is a striking coincidence in time and space between mining activity and seismicity. The seismic energy released per square kilometer in the gold mining districts is several hundred times greater than elsewhere in southern Africa (Durrheim et al., 2006). The character of seismicity differs significantly between the goldfields. These differences can be explained by differences in geological structure and the consequent mining layouts. Many of the seismic events in this mining area occur close to the working face. While mining certainly triggers some large events in the gold mining districts, there is no doubt that stress changes due to mining-induced seismic events (Durrheim et al., 2006).

Over time South African mining and environmental legislation has developed from past practices where mines were often left abandoned when the ore was depleted or grades fell to sub-economic values. Unfortunately, formal mine closure only became a legislative requirement in 1980 resulting in the legacy of abandoned mines many of which could be legally classified as derelict and ownerless and will require intervention by the state in order to address safety, health and environmental legacies. Early legislation focused on surface rehabilitation which provided a basis for environmental management and the rehabilitation of the affected environment of prospecting and mining for the first time. The initial requirements for mine closure entailed the concept of 'safe-making of the surface of mining land' and the submission of a basic 'rehabilitation plan'. The Minerals Act, 1991 (Act 50 of 1991) was the first act that paid appropriate attention to mine environmental management. Prior to the passing into law of the Minerals Act, many mining companies:

> *"used irresponsible mining methods with no regard towards protecting the environment and had often shirked their responsibility towards environmental rehabilitation by leaving an area unrehabilitated prior to them being liquidated or leaving the country"* (Swart, 2003).

Currently operating mines are required to rehabilitate any environmental damage that may occur during mining and to make financial provision for the rehabilitation of such damage. The new South African legislation governing mine closure, the Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002), presents a holistic cradle–to–grave approach to prospecting and mining by balancing economic benefits from mining against social and environmental concerns to achieve sustainable development. The existing legal framework in South Africa is such that the environmental responsibilities and the financial implication remain with the mine lease holder until a closure certificate is issued by the DMR, upon which the environmental liabilities can be transferred to a competent person. Many mining companies only complied with the minimum requirements to environmental management and rehabilitation. An additional challenge in governing mine closure is the fact that the impacts from mining cross-cuts the jurisdictions of a number of government departments, all of whom are likely to play an important role in the management of legacies.

2 Background on the regional mine closure concept

To deal with closure challenges where mines have an inter-connected and/or an integrated environmental impact the DMR initiated the Sustainable Development through Mining (SDM) programme in 2005 to provide direction and impetus for the role of mining in sustainable development (van Tonder et al., 2008a). Through this programme, the need for regional mine closure strategies was identified and the DMR, in partnership with the Council for Geoscience (CGS) has developed the first of these: *The Strategy for Regional Mine Closure in the Witwatersrand basin* (van Tonder et al., 2008a). The initial phase of the development and implementation of this strategy is detailed in this paper and comprises four main components: (1) the subdivision of the Witwatersrand Basin into regional closure areas, (2) the compilation of all relevant background information, (3) the development of the strategy based on socio-economic and environmental considerations, which amongst other things includes water management plans, based on the information gathered during the initial phase, and (4) the development of a proposed implementation plan for the management of the various closure areas.

The concept of the regional mine closure strategy (RCS) (Pulles et al., 2005) stems from the fact that in many areas, particularly the Witwatersrand Basin, a number of large underground mines are interconnected. This has led to the sharing of the responsibility to dewater the mine voids in some instances. However, in many instances as the mines within a region closed, the dewatering responsibility rested on the remaining mines, often until one mine is left with the liability for an entire mining basin. This translates to financial risk, which can become a driver of disinvestment in the mining industry with a resultant potential loss of jobs and associated economic activity. To prevent a decline in investor confidence due to the risk posed upon an operation by neighbouring/interconnected mines a coordinated approach to closure, applicable to all mines within a given region, was needed. Government thus needed to consider a move away from the casual approach of the past to a more regulated approach regarding mine closure that is applicable to all mines within a given region. In order to address the diverse and complex issues related to mining and closure, the concept of RCS was proposed. This provides a broader and more inclusive perspective than what individual mine closure plans are able to provide. The regional mine closure approach has been proposed as a means to address cumulative and inter-mine environmental impacts. This approach moves away from the historical site-specific approach to mine closure, allowing a more integrated approach to be applied in regions where more than one mine has led to a combined environmental impact.

However, over and above the water issues, mines have other significant environmental impacts that need to be addressed on a regional basis due to the cumulative effect. Post-closure land use, for instance, will need to fit into regional development priorities and therefore cannot be treated in isolation, and also needs to be addressed within the RCS. Furthermore RCSs also need to address the environmental legacies of past mining, as well as the potential for impacts occurring in the future, after closure has been granted. The contribution of derelict and abandoned mines to the overall impact of unsustainable mining practices in a regional mine closure area is acknowledged and is dealt with in the national strategy for the management of derelict and ownerless mines. There might be instances where a specific mine in a region plays no role in the cumulative and integrated impact and does not pose any threat to the neighbouring mines and vice versa. In such instances that mine may be excluded from the regional mine closure area and only the individual mine closure plan is applied. A simple criterion for the decision whether to place mines in a regional closure area is to ask the question whether one mine in a region can close without having an impact on the remaining operating mines in the region. Furthermore, the impacts of mines cut across commodity lines and therefore RCSs may include multiple commodities within a region.

A RCS is different to a mine closure plan in that the former considers the various issues that are relevant to mine closure on a broader integrated level and develops a strategic framework within which individual mine closure plans will fit. RCSs aim to provide a framework within which individual mines can develop closure plans which address broader development priorities within a region as well as possible cumulative impacts due to the activities of a number of mines. Thus, it is paramount that the RCS be developed in collaboration with the relevant authorities, relevant mining industry (employers and employees) and the interested and affected parties (I and APs) that fall within that region.

The purpose of the RCS is therefore not to replace individual closure plans, but to provide a set of actions, norms and standards that the closure plans of the individual mines in a region must comply with in order that all of these mines can eventually close effectively. Reasons for a RCS can be summarised as follows:

- To address the issue of dewatering in interconnected mines.
- To address environmental impacts of past, current and future mining and closure on a regional basis.
- To provide a regional framework within which individual mines within the region can plan their mine closure.
- To address the impact of cumulative pollution arising from mining within a region.
- To address socio-economic issues arising from mining on a regional basis.
- To ensure that post-closure land use is in line with the regional development priorities.

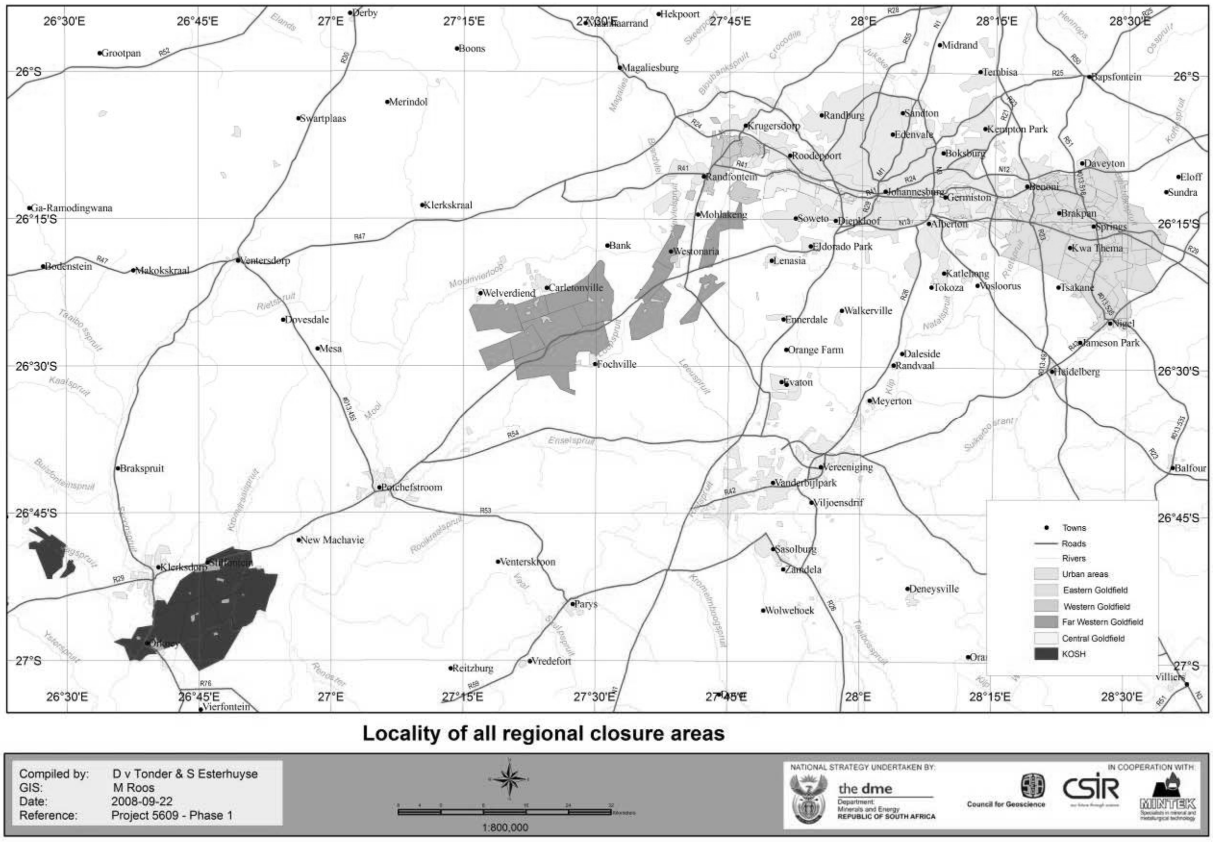

Figure 1 The Witwatersrand Basin

A RCS would involve aspects of a mine closure plan, but would also involve strategies of cooperation between mines to achieve goals of sustainable closure, without compromise to adjacent mines and ensure regional protection of resources, such as groundwater. The main vision of regional mine closure is therefore to prevent or minimise adverse long-term environmental impacts, and to create a self-sustaining natural ecosystem or alternate land use (van Tonder et al., 2008a) based on an agreed set of objectives. Poorly planned closure strategies or lack of closure strategies have the potential to cause long lasting negative economic impacts on the community. While the immediate impact is the loss of jobs and income used to support the growth of a community, there is also a direct and indirect impact on local employment, businesses, and the sale of goods and services. The negative impact on the economy can give rise to social impacts, such as a rise in unemployment, increased crime levels and decreasing standards of delivery in social services (van Tonder et al., 2008a).

2.1 Process

A steering committee was established early in the process. The draft strategy documents were taken through a limited stakeholder consultation process which included consultation with the government departments including municipalities in the affected areas. The draft regional gold mine closure strategies were peer reviewed and posted on the CGS website for public comment. Interested and affected parties were also invited to view and comment. Issues raised by various stakeholders were taken into account in the final draft.

3 Key generic proposals emanating from the RCS

3.1 Environmental protection

Inter-mine impacts and cumulative impacts on the environment are the main reasons for implementing RCSs for mines in the Witwatersrand Goldfields. These impacts are caused by the underground interconnection of mine workings and consequent inter-mine water flow. In addition, windblown dust from tailings, contamination of surface water and wetland systems by heavy metals and acid mine drainage and the radioactivity risk are considered as significant cumulative impacts of mining. This effectively prevents any individual mine from closing without its impact being shared by the other mines within the region. When mining ceases re-watering will occur and the assumption is that contamination, ground instability and seismicity will continue for a period post-closure. However, these assumptions need to be verified and therefore continuous monitoring needs to be done from present to post-closure.

An important consideration relating to the concerns about water contamination in post-mining times is that the surface water entering the Witwatersrand Goldfields is already contaminated before entering the mine void. Water polluted by leachate from mine dumps shows characteristically high sulphate concentration and will form the greatest threat to groundwater quality after closure. Surface and groundwater interactions suggest that poor quality surface waters may impact on dolomitic aquifers. Conditions exist for U to be transported in solution in the surface and groundwater. It is possible that radiogenic material may migrate, dissolved in groundwater, to be consumed at some other point where radioactive contamination may not be expected. The generic water management options proposed by the RCS for the Witwatersrand Basin is to manage water by integration and to keep clean water clean.

3.1.1 Water management by integration

In order to manage mine water, it may be economic to consider the management of water, e.g. for the purposes of treating before discharge or disposal to surface, at a single central locality for a particular region where there are hydraulic interconnections between mines. This is referred to as management by integration. In the case of flooding mines that are predisposed to decant onto surface environments via multiple decant points or diffuse zones, the management of the water at a single point makes more sense, even from the point of view of the economies of scale of constructing a single water treatment plant to handle large volumes of water at considerably lower unit costs. Integration of surface discard facilities also exploits the management by integration principle by limiting the future sources of acid mine drainage generation.

3.1.2 Keeping clean water clean

The water management principle of keeping clean water clean is a desired principle to attain. This means that any mine water management interventions that cause the deterioration of the quality of water resources that could have been kept clean and free of mixing with polluted water will not be permitted (van Tonder et al., 2008a). Limiting the amount of water entering into the mine void, where pollution is considered inevitable, will also reduce the cost of cleaning water.

43.1.3 Reducing pumping costs

In the normal course of deep mining operations, it is necessary for mine operators to embark upon and maintain expensive pumping from depth in order to keep a safe, unflooded environment for underground mine workers. At present, the State subsidises a component of actual expenses incurred due to pumping at marginal gold mines. Any intervention that reduces the costs of pumping is desired and encouraged. Such interventions may include, amongst others:

- Groundwater interception at or near recharge areas in order to prevent groundwater incursion into mining regions (van Tonder et al., 2008a).
- Engineering measures to prevent ingress of water from surface to underground mine voids, e.g. canalisation over undermined areas, river channel diversion schemes, tunnels, grouted barriers etc. (van Tonder et al., 2008a).
- The use of more efficient pumps leading to a consequent reduction in electric power consumption.
- Increased rate of pumping operations during off-peak periods and reduced pumping rates during peak periods to maintain safe underground water levels.

Some general principles apply to the development of mine management options, interventions and choice of solutions. These include:

- Management of groundwater recharge.
- Management of ingress to underground mine voids.
- Management of flooding underground mine voids.
- Management of decant of mine water to surface.

3.1.3.1 Management of groundwater recharge

Principles of groundwater recharge management are that the interception of groundwater is a desirable outcome. Studies that lead to interventions that intercept groundwater from recharge areas before such water can infiltrate and finally report to the underground voids of mining areas are strongly supported. Specific options for managing groundwater recharge could involve groundwater interception well fields, groundwater drains, or grout curtains.

3.1.3.2 Management of ingress of water to underground mines

Water can ingress to underground mining voids through pathways formed by natural features such as geological faults, fractures and fissures, open shafts, or via connections to surface through shallow undermining. Sources of direct water ingress into mines are precipitation, especially storm events, and collection of stormwater and other run-off. Closure of openings through properly designed, stoutly constructed and reinforced concrete structures or polyurethane foam is recommended to limit water entering directly into underground mine operational areas and voids in mined out sections of mines (van Tonder et al., 2008a).

Other key recommendations include building canals where possible to allow water to bypass shallow undermined areas or other natural conduits, diversion of rivers for similar purposes as above, and in situ rock barriers or construction of grouted barriers minimising the flow of water into active mine workings (van Tonder et al., 2008a).

In situ rock barriers are created by refraining from mining within specific areas to leave natural barrier pillars, whereas, artificial barriers may be referred to as 'plugs' or 'dams', and are typically mass structures of concrete.

3.1.3.3 Management of flooding underground mines

Flooding of underground mine voids is generally not an insurmountable problem while mines are in an operational phase. Mine dewatering through pumping in deep mines is a standard and necessary practice for reasons of safety of miners and access to the orebody. Thus, during the operational phase, mines are kept dry in their operational areas. Where mines are marginal, however, and the necessary dewatering is intensive, the costs of pumping from great depths may be uneconomical. This may lead to the early closure of mines.

For some mining operations, plugging off worked-out sections of the mines may reduce the immediate quantity of mine water to be pumped out from underground. Such a practice should be viewed with caution, however, as it could allow for uncontrolled flooding of the worked-out sections, and could consequently lead to uncontrolled decant. According to the 'polluter pays' principle, the mines are still liable for the detrimental environmental effects and impacts of their operations. Therefore, even if worked-out sections are plugged off from current working sections of mines, water management interventions still need to be applied to the former.

Mine water environmental management plans and specific interventions are required from the responsible mines in such instances and should be enforced. Mining operators are supposed to update their mine closure plans to include specific plans to avoid uncontrolled decant from flooded sections of their mine in four timeframes: immediate, short term, medium term and long term.

3.1.3.4 Management of decant of mine water to surface

The uncontrolled decant from flooding mines is undesirable and not to be tolerated because of the potential impact on the environment, human health and safety as well as structural damage due to ground instability. It has been recommended that the water be maintained at an environmental critical level (ECL), which will prevent surface and groundwater contamination (van Tonder et al., 2008a). It has also been recommended that in all basins where mining can still continue, water levels must be maintained at an appropriate level for mining. Mining companies and prospective mining companies will need to make a commitment towards this. After cessation of underground mining, any option which allows water to recover to decant level and decant freely is not seen as sustainable, owing to the unpredictability of the decant process. So far the ECL has only been defined for the West Rand regional closure area and needs to be established for the other regional closure areas.

3.1.4 Apportionment of mine water pollution

The mines, including derelict and ownerless workings, should be given an opportunity to apportion liability amongst themselves based on the polluter pays principle. If an agreement is reached it should be legally binding to provide for recourse in the event of non-fulfilment of the agreed actions. This agreement would need to be renegotiated as new players enter the region and some stop operating. Notwithstanding, in the event of an agreement not being reached the Department of Water Affairs has the mandate to issue a directive on the water pollution clean-up liabilities. An example exists in the West Rand basin where owing to the integrated nature of the impacts of four mines in the basin, it was not possible to unequivocally apportion impacts to individual mines. A simple apportionment model, where impacts are apportioned according to the surface area of the mine lease areas was proposed for the West Rand Goldfield to apportion responsibility for the management of decant water. This was superseded by a more complex model, proposed and agreed to by the mining industry, based on a number of parameters such as size of mine residue deposits, etc. The numerical values determined in these two models were very similar to one another.

A generic procedure for apportionment should therefore be as follows:

- All pollution sources and impacts which are limited to a specific mining right area will be the responsibility of the mining right holder.
- Integrated impacts out of mining rights areas will be apportioned using the simple model described above, unless the mining rights holders agree to an alternative apportionment.

3.1.5 Dealing with acid rock drainage

Acid rock drainage (ARD) management plans are long-term processes and depend on future predictions with significant inherent degrees of uncertainty. Therefore, a regular validation of predictions and management plans is essential in ensuring that the plans remain relevant. Additionally, regular review of performance of the implemented ARD management plan will highlight ways of doing things better and will maximise the opportunity for the mine to identify and implement pollution prevention strategies in preference to pollution mitigation strategies. Aspects to consider in the development of an ARD management plan include ARD source, maturity, characterisation and prediction for new, operating and closed mines as well as model calibration and selection of control technology.

3.1.5.1 Progressive rehabilitation

The ability to progressively rehabilitate sections of the mine site as they become available is an important way of reducing the long-term closure liability and is encouraged by the MPRDA (Act 28 of 2002). Actively rehabilitating areas during the operational stage can usually be cost effective. Benefits of progressive rehabilitation include:

- Reduction of the overall un-rehabilitated footprint of the mine.
- An ability to trial various options and demonstrate rehabilitation outcomes to wider community.
- Showing commitment to stakeholders and employees that the mine has an active mine rehabilitation programme.
- Reduction of the overall closure costs.
- Reduction of the risk of failure and ultimate liability.
- Reduction of the rehabilitation bond posted with regulatory authorities.

3.1.6 Radioactivity

The objective is to minimise the risk of radioactivity in mine related water to human health; to ensure the management of radioactive waste in South Africa is in accordance with national objectives and recognised international principles as recognised in Government Policy; and to monitor the radioactivity in the closure areas effectively. Recommendations from the strategy is that regular airborne radiometric surveys of mining areas and the areas downstream and downwind on which they impact be done. Furthermore, documentation of all sources (point and diffuse), which exist with high confidence monitoring of dust and airborne radon impacts both on mine sites and in the surrounding areas be done along with detailed monitoring of downstream water quality, including radiological parameters and studies of any water-sediment processes which may be concentrating radionuclides in river sediments. Collaboration between mining companies (and the State) regarding monitoring of shared offsite impacts is proposed. A collaborative clean-up plan will ensure that many off-site impacts are addressed prior to mine closure.

3.1.7 Seismicity

Due to increased mining activity seismic incidents increased. Similarly it is expected that reservoir induced seismicity will also increase in the future as re-watering takes place. Steps should be taken to improve the quality and ensure continuity of seismic monitoring, especially as mines flood, change hands or close. Monitoring of seismicity by the proposed monitoring committee, consisting of all the mines in the area as well as parastatal organisation and municipality, will be crucial in understanding the impact of rewatering.

3.1.8 Ground stability

Catastrophic sinkhole development occurred in areas affected by dewatering of mines. Renewed movement and new sinkhole formation are expected during rewatering after mine closure. The potential of dolomite instability is related to the karstic nature of the dolomite. Areas underlain by dolomite need to be identified in order to put in place precautionary measures to ensure safety.

3.1.9 Dust

Limited information on the air quality/dust impact around the Witwatersrand basin gold mines is available. Dust emissions associated with South African gold mines are generally well defined point source dust emissions from surface discard facilities. As a mine-generated pollutant, dust has numerous side effects: the large, more visible particles are regarded as a visual nuisance and affect aesthetic values, (Felleman, 1986) while particles under 10 µm are invisible to the naked eye and have the potential to cause associated impacts on human health (WHO, 1999). Sufficient attention was not paid to the potential that exists for cumulative impacts given the co-location of mining operations and other sources. The management and control of mineral waste-generated pollutants from gold mines can take many forms. However, the ultimate goal in residue deposit management is to minimise the liability of the mining operation after closure. Economic and regulatory requirements tend to provide a starting point from which managers can initiate their planning, with technical goals concentrating on:

- Stabilisation of the residue deposit.
- Provision and maintenance of hydrological control.
- Seepage control.
- Integration of the man-made landforms into the surrounding landscape.
- Minimisation of the need for water treatment, monitoring and after care maintenance.

It is recommended that dust management plan(s) for the different goldfields of the Witwatersrand Basin be developed with input from the key stakeholders such as the relevant municipalities; as the latter are required to include air quality management plans into their integrated development plans in accordance with the National Environmental Management: Air Quality Act (Act 39, 2004). The decentralisation of air quality management has brought new responsibilities to local government. The Municipal Structures Act, together with the local government: Municipal Systems (Act 32, 2000) have firmly established local government as an autonomous sphere of government having specific functions defined by the constitution. This will ensure that all realistic, best practice measures to prevent or minimise the generation of dust from mining activities will be implemented. Furthermore, the DMR should assist the municipalities with plans to manage dust from derelict and ownerless discard facilities as well as those belonging to non-operating mines, with input from other key role players in the region.

4 Critical success factors

In order for the strategy to be implemented there are a number of key success factors.

4.1 Post-closure monitoring

Provision should be made in closure planning for an adequate period of maintenance and monitoring of cumulative impacts. A good example of cumulative impact monitoring would be the monitoring of downstream radioactivity impacts on sediments and surface water resources. Monitoring should be designed to demonstrate that completion criteria have been met and that the site is safe, stable and has achieved the objectives set during the planning process. It is unlikely that such conditions can be demonstrated in less than 5 years following cessation of mining. Of particular importance is the development of support mechanisms for the maintenance and monitoring phase, when operational support (accounting, maintenance, etc.) is no longer readily available. The need for maintenance recognises that not all closure strategies will be initially successful. All closure situations are unique, and although past experience and good planning can minimise the risks of failure, some remedial activity will usually be necessary. Where the opportunity exists to do rehabilitation progressively this should be taken.

Typical monitoring programmes that support a mine closure plan include:

- Baseline monitoring at the early stage of mining to set the environmental baseline against which closure will be measured.
- Monitoring and understanding of all pollution sources and impacts during the operational phase to evaluate the liability.
- Initial closure monitoring after rehabilitation to evaluate success.
- Long-term monitoring, commencing after rehabilitation to evaluate progress and post-closure success.

For socio-economic monitoring, it is recommended that social mapping of baseline investigations and documentation of the social systems and cultures before commencement of mining operations be introduced (in the case of new mines). Using such tools will assist in monitoring social and economic impacts and minimising negative impacts.

4.2 Ongoing management

It should be the objective of all mine closure programmes to achieve a final land use which requires limited ongoing management and maintenance. However, under some closure scenarios (such as treatment of acid mine drainage) there may be a need to provide long term, active management and/or monitoring of the closed site. The post-mining management and monitoring requirements for shared residual impacts need to be assessed and adequately provided for. The mechanism for funding any post-relinquishment management and monitoring that may be required needs to be determined by the lease holders, the regulatory authorities and stakeholders.

Typically, post-relinquishment management that may be required can include:

- Noxious weed control.
- Exclusion or control of grazing animals.
- Control of public access.
- Fire management.
- Maintenance of safety signs and fences.

4.3 Addressing information gaps and data management

The information gaps identified need to be addressed in order to complete the development of the RCS. However, it should be noted that complete scientific certainty is not a prerequisite for appropriate action to protect the environment where there is a risk of serious adverse impact (O'Riordan and Cameron, 1994; van Tonder et al., 2008b). Having the best information to make the best technical and social decisions in closure planning requires the collection, assessment and management of all environmental, social, economic and mining related information.

In the past, when mines were closed and the tenure has been relinquished or surrendered, many of the records of activities that occurred on the sites were lost, destroyed or inadvertently disposed of. These records, while considered of no further use to the company that once operated the site, are valuable to governments, potential future land users and stakeholders. The retention of mine records is important because they provide:

- A history of past developments.
- Information for incorporation into state and national natural resource data bases.
- The potential to improve future land use planning and/or site redevelopment.

Targeted research will assists both government and industry in making better and more informed decisions. One of the challenges facing all stakeholders is making rational decisions with limited information or knowledge on which to base these decisions. It is in the interest of all parties to be involved in this process to ensure there is a balanced outcome and that the relevant issues are addressed. Transparency and full consultation between all stakeholders during the regional closure planning and implementation processes through sharing of information will be essential for the success of the strategy implementation.

4.4 The need for buy-in from the key role players

Regional mine closure is a paradigm shift from the current closure process which only deals with closure on an individual mine basis and does not take into account cumulative impacts and opportunities of mine closure in a region. Thus, the necessary resources (human, financial, time) should be put into place by the DMR to engage with the key role players in order to obtain their buy-in into the concept and the associated roles and responsibilities that these key stakeholders need to fulfill in order to make this a reality in South Africa.

Advance planning and close cooperation by the mining companies with local authorities, communities and NGOs is a key to successful mine closure and achievement of post mine closure stability. It is clear that the RCS cuts across a number of government departments. Thus, in order to finalise and implement the strategy, there is a need for the formation of partnerships. It is acknowledged that effective partnerships can be difficult to forge and to make operational on a sustainable basis.

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

5 Implementation

Well developed implementation plans consist of two distinct sequential phases; implementation planning process and the actual implementation. In the case of the RCS, coordinating these stages is a critical step in sustainable closure of mines within the regional closure areas.

The following considerations need to be taken into account in the implementation plan:

- Robust and inclusive implementation planning process.
- Accountability for plan implementation.
- Resources needed to assure conformance with the implementation plan.
- Ongoing management and monitoring post mine closure.

The assumption is that all mines in the regional closure area have an impact on the environment and should attempt to operate in a sustainable manner and reduce their individual and cumulative impacts. The RCS has a relatively long-term vision and strategic initiatives should be placed in a feedback loop, complete with measurements and planning linked in a Deming Cycle (plan-do-check-act cycle). This approach is based on the belief that our knowledge and skills are limited, but improving. Especially at the start, key information may not be known. Firstly, the strategy is reviewed to assess the current level of environmental performance and knowledge gaps, a plan is then drawn up of how it can be improved and gaps eliminated. Objectives and targets are set to implement the various strategy plans. Once these plans have been implemented they are checked to see if they are functioning effectively with the original objectives in mind. This is done through monitoring, audits and highlighting non-conformance and corrective or preventative actions. Finally, any recommendations for improvement identified in the checking phase are implemented. The cycle then starts again so that the system is continually improved and refined to accommodate changing circumstances.

There is a need for a structure to be accountable for the RCS implementation. At present the Government task team is accountable for mine water related issues. There is a need for a structure that is accountable for RCS in its entirety, i.e. the environmental, social and economic and governance issues. Since the skills required for reviewing and monitoring the implementation of the RCS cuts across the mandates of a number of government departments, it is proposed that an agency be formed to review the implementation of the RCS once the performance objectives and standards are set. This agency's duties would include the following:

- An outline of the responsibilities, accountabilities and proposed methodologies required to achieve successful closure within a RCS context.
- Co-ordinate monitoring and reporting on adherence to RCS.
- Co-ordinate self assessments of mines against the closure scorecard, which includes agreed performance criteria addressing environment, social and economic outcomes.
- Propose processes dealing with areas that fail to meet performance criteria, including corrective action.
- Keep all records related to RCS.
- Audit the implementation of RCS.

It should be noted that the implementation of the RCS is going to be resource intensive in terms of financial, knowledge generation and management, human resource and time. Thus, the key stakeholders need to be committed to the implementation of RCS. In order for the strategy to be implemented there needs to be an implementation plan. As discussed previously the development of this plan cannot be done solely by the mines or by the government. There is also a need to involve other key role players. The tasks would also include setting up a closure scorecard for each region. The scorecard will inform the roles and responsibilities of the different stakeholders.

5.1 The role of the mining industry

Mining companies need to commit to the process of developing and implementing RCSs by:

- Active participation in closure committees.
- Proactive development of closure plans which are compatible with the agreed upon RCS.
- Commitment to the completion of the requirements of their own approved closure plans within the prescribed timeframes.

5.2 The role of communities

Communities need to play an active role in closure committees and provide constructive input into closure objectives. It should be remembered that community-based and advocacy organisations play an invaluable role as watchdogs and that they will, to some extent, be the eyes, ears and conscience of the closure structures. They will also be the ones who have to bear the cost of any residual and latent impacts.

5.3 The role of the state

The state has a number of roles to play in the implementation of the regional closure strategies:

- The primary role is that of regulator.
- In addition, the state needs to play the role of facilitator.
- Within the state agencies involved, local government bodies need to take a leading role in the identification of end-land uses and appropriate remediation targets.
- Finally the state needs to provide high confidence information to stakeholders to ensure responsible closure.

The way forward involves the setting up of region specific performance objectives, criteria and standards. The closure committee will engage on the implementation plan with roles, responsibilities and timelines allocated to all stakeholders. The broad agreement on the way forward will culminate in regional mine closure scorecards set-up by the closure committee and ultimately the alignment of individual mine closure plans and amendments to EMPs.

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