LAND REHABILITATION GUIDELINES FOR SURFACE COAL MINES

Coaltech Research Association
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GUIDELINE INTENT

The initial *Guidelines for the Rehabilitation of Mined Land* was compiled in 1981 (supported by the Minerals Council of South Africa, then referred to as the South African Chamber of Mines), with a subsequent update approximately 26 years later in 2007. Since then, notable changes to South African mining rehabilitation-related legislation have taken place, as have mining houses' needs to update in-house standards, guidelines and protocols to focus on site-specific rehabilitation processes.

The Land Rehabilitation Society of Southern Africa (LaRSSA) has been established to provide a platform for sound technical advice and guidance, as well as access to an experienced network of interdisciplinary practitioners, academics, regulators and companies, whose expertise was used to update the earlier guidelines, with specific reference to Surface Coal Mined Land.

The intent of this *Land Rehabilitation Guideline for Surface Coal Mines* is as follows:

- To provide a consolidated, up-to-date document covering the key aspects of good practice planning, implementation and ongoing management of surface coal mines from a land rehabilitation perspective;
- To provide standardised guidance for setting corporate standards and policies, and site-specific land rehabilitation plans;
- To emphasise the importance of upfront, and aligned, mine and rehabilitation planning that focuses on setting appropriate rehabilitation targets, that are aimed at achieving an agreed post-mining landscape capable of supporting a mixed suite of future uses, and which will ultimately streamline and optimise business expenditure; and
- To provide technically sound, simple, and practical approaches for implementation by all levels of land rehabilitation practitioners, mine planning teams, and administrating regulators; all of whom are responsible for mining-related land stewardship in our country.

Although this Guideline includes relevant land rehabilitation actions for all types of surface coal mined land, it has been updated based largely on experience within the Mpumalanga Coalfields, in the Republic of South Africa (RSA). Although its actions could be implemented on surface coal mines across the country, its intention is not to provide region- or site-specific rehabilitation specifications or relinquishment criteria. *Just good practice guidance*.

This Guideline is a collection of existing knowledge and information relevant at the time of compilation. There may be gaps and omissions, and this document should be reviewed and revised on a regular basis.

Raina Hattingh	**Phil Tanner**	**Mark Aken**
Guideline Update	Senior Reviewer	Senior Reviewer

Disclaimer

This Guideline has been developed by Land Rehabilitation Society of Southern Africa. It was undertaken as a project supported and endorsed by the Coaltech Research Association (Coaltech), a research subsidiary of the Minerals Council of South Africa (MinCoSA). The efforts of all contributors are gratefully acknowledged, specifically the LaRSSA Council Members of 2017/2018.

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GUIDELINE LAYOUT

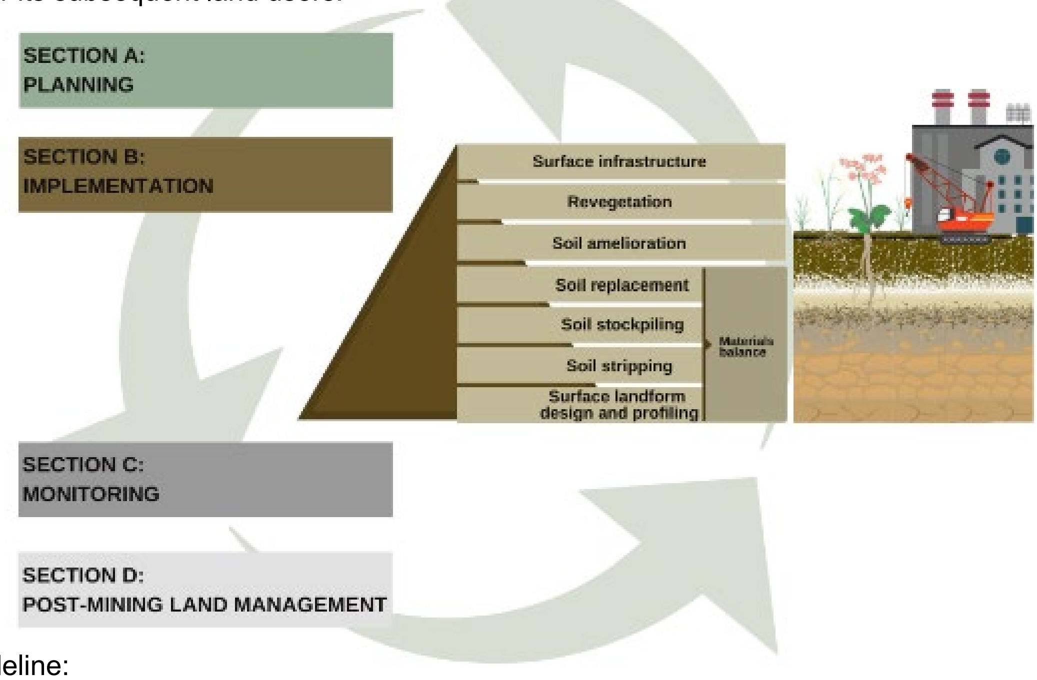
The Guideline comprises the following sections:

Section A: Planning - Sets the scene for surface coal mining-related land rehabilitation, understanding South African statutory requirements and defining the need for dedicated upfront land rehabilitation planning and design in conjunction with operational mine planning.

Section B: Implementation - Provides the in-field land rehabilitation context, challenges and opportunities for on-site implementation. It further provides generic rehabilitation objectives, implementation actions and suggested relinquishment criteria for the core components of land rehabilitation.

Section C: Monitoring - Provides guidance on monitoring protocols needed to identify rehabilitation progress, as well as to determine the need for corrective action that would require refinement of implemented actions.

Section D: Adaptive land management - Documents the key aspects of ongoing land management, post-rehabilitation, to manage residual and latent risks, aiming to ensure rehabilitated mined land provides long-term opportunities for its subsequent land users.



Throughout the Guideline:

Concepts, ideas or notes considered key to land rehabilitation are provided in green blocks:

Appendices are highlighted in orange blocks:

Additional resources that are considered valuable as further guidance for land practitioners are highlighted in yellow blocks:

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INTRODUCTION

Mining-related land rehabilitation is often a 'wicked problem' – a term used to describe situations that are highly challenging, contradictory in nature and dynamic[1]. Land practitioners need to understand, consider and integrate a large variety of ecological, social, political, cultural and economic aspects. These aspects are also continuously changing over time as the mine's operating landscape changes and are often relevant over large geographical footprints. Adding to the challenge are the often competing land rehabilitation objectives, where, for example, flatter surface profiles may improve land capability at the expense of increased water infiltration through backfilled spoils; where corporate values in land stewardship within the industry range between simply achieving minimum regulatory compliance and aiming to achieve international best practice; and where it becomes difficult to manage stakeholder expectations when they hold divergent views on post-mining land use.

Further challenges are presented in trying to understand the multitude of scientific disciplines required to define and continually assess the rehabilitated landscape; and in having to comply with often competing and onerous local and national legislative policies that are meant to guide overarching site-specific rehabilitation planning.

Although the above challenges exist, there are also many advantages that can be gained by an operation (at a local level), and for the country (at provincial and national levels), by striving for successful land rehabilitation. These opportunities can only be harnessed through the implementation of good practice land rehabilitation principles.

In the past, land rehabilitation on coal mines frequently followed the path of minimum effort to achieve legal compliance. However, a global awareness of the anthropogenic pressures on the earth has resulted in the incorporation of sustainable development principles into international legislation, global governance structures and individual companies' operating procedures. Mining, with its significant environmental and social impacts, appears to have embraced this concept in its rehabilitation and closure planning.


Photo: WF Truter - 2018

Land rehabilitation is only one aspect of achieving eventual mine site relinquishment. Other biophysical components such as water and air also need careful attention. Similarly, social risks and opportunities related to both employees and

[1] Barkemeyer, R., Stinger, L.C., Hollins, J.A. & Josephil, F. (2015): Corporate reporting on solutions to wicked problems: sustainable land management in the mining sector. Environmental Science & Policy. 48, pp. 196 – 209.

their dependents, as well as relevant mine-affected external stakeholders should be evaluated, and addressed, as appropriate. Fundamentally, the success or failure of implemented rehabilitation activities depends on the mining company dedicating the required resources, both in cash and manpower, to complete the required work to the correct standard.

The principles, objectives and actions defined in this Guideline are not new to the mining and land rehabilitation fraternity. Neither are they complex or costly - if planned and implemented timeously. The Guideline encompasses up-to-date global thinking, using case-studies to illustrate successes and challenges.

The Guideline should be used to guide an opencast coal mine's successful land rehabilitation planning and implementation, from project exploration and feasibility through to eventual site relinquishment.

SECTION A: PLANNING

> *"If we design to engage the public; if we interpret these [mine] sites in ways that allow understanding; if we admit that good science is always necessary but sometimes not sufficient; if we use public history to inform the future, we create the opportunity for much broader public participation in reclamation issues. We may even do some small things to help rekindle a reason for pride in coal"*[2].

1. SETTING THE SCENE

1.1. Surface coal mining context

Mining is the 5th largest industry in the world and has a significant role to play in underpinning the prosperity of current and future generations. South Africa, specifically, is the home to 3.5% of the world's coal resources and is ranked as the 6th largest coal-exporting nation[3].

Mining takes many forms, but in its simplest division it either involves surface open-pit mining (where the pit overburden material is relocated to permanent overburden dumps); surface strip-mining (where the pit overburden material is replaced in an adjacent open mined-out section); underground mining with minimal surface disturbance (e.g. bord-and-pillar mining to specified safety factors); and underground mining with significant surface disturbance (e.g. shallow longwall mining). It is noted that there are also specialised coal mining methods of hydraulic mining and gasification (Figure 1).

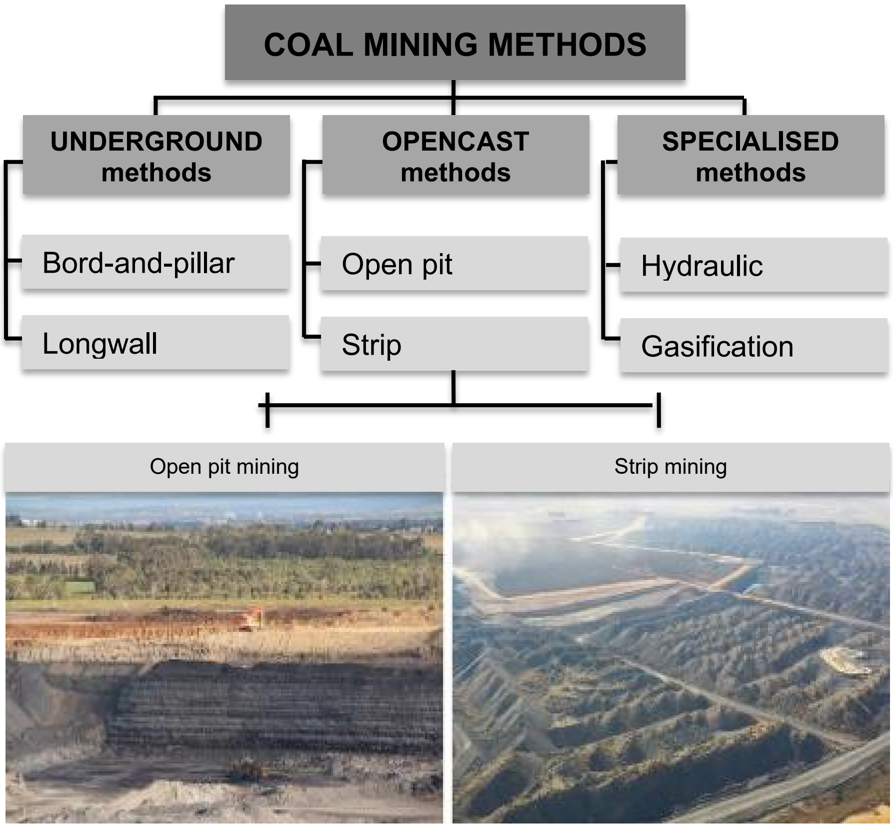

Figure 1: Various methods of coal mining

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[2] Comp, T.A. (2013): From environmental liability to community asset: mined land reclamation. Proceedings of the 2013 International Mine Closure Conference. Cornwall, United Kingdom. pp. 5 – 7.

[3] Minerals Council of South Africa (2017): Integrated Annual Review 2017.

Receipt of a Mining Right (MR) implies authorisation of pre-assessed environmental impacts with effective environmental management plans (EMPs) to mitigate the impacts. The Environmental Authorisations (EAs) are based on dedicated, site-specific Environmental Impact Assessments (EIAs), which are mostly compiled by independent environmental practitioners (EAPs). The findings of the EIAs are presented to Interested and Affected Parties (I&APs), and other stakeholders, through a thorough public review process. EIAs examine the potential environmental impacts of the project and weigh these up against the financial and community benefits of the project so that a logical decision can be made on whether or not to allow mining to proceed.

A changing lifecycle – mining to rehabilitated, functional land

The EIA/EMP process itself is well-designed, however, there is often inadequate information available at the time of EIA/EMP compilation (project prefeasibility or feasibility stages) to develop scientifically sound EMPs. In addition, EAPs frequently lack the technical experience to identify suitable mitigation measures with this limited project knowledge. There is also often a lack of willingness and expertise on the part of the regulators to police mine performance against EMP requirements, resulting in substandard outcomes. In addition, even though good EMPs provide the necessary guidance on how to mitigate impacts, implementation by the mine team is also often inadequately executed.

Although good EMPs do exist that provide the actions for closing an operation at the end of its life, many EMPs lack this focus in detail. This remains a fundamental flaw in many older, and some current, EIA/EMPs. Accordingly, dedicated upfront surface landform (material movement and optimisation) plans, rehabilitation (soil, land capability, vegetation) plans, and mine closure plans are now seen as the key plans required to ensure successful site rehabilitation and closure.

NOTE:

This Guideline focuses on surface-related coal mining - both open-pit and strip-mining

1.2. Land rehabilitation context

1.2.1. Mining lifecycle and rehabilitation

For the purpose of this Guideline, the following stages are defined within a mine's lifecycle:

- Design and permitting;
- Construction;
- Operations (and progressive rehabilitation);
- Decommissioning (and final rehabilitation);
- Post-mining (monitoring and care- and-maintenance); and
- Mine closure (site relinquishment).

Once successful achievement of rehabilitation criteria has been demonstrated and regulators are willing to sign-off on this success, site relinquishment to a new landowner is possible. Although the term *mine closure* is often used to describe the period after decommissioning, once operations have ceased, it is actually the point at which eventual sign-off of the rehabilitated land to a new/alternative owner is achieved. Mine closure is the point at which a closure certificate is issued to the mining company.

For land rehabilitation, mine closure is the ultimate goal - the point at which the reinstated land uses on the rehabilitated land have been proved to be environmentally, socially and financially sustainable within the post-mining landscape.

Figure 2 illustrates the six-staged mining lifecycle, as well as the integration of key mining environmental management plans (EMPs), Social and Labour Plans (SLPs), Rehabilitation and Closure Plans across this time frame. It further illustrates an indicative implementation timeline (level of activity) for concurrent rehabilitation activities over this lifecycle, for both open pit and strip-mining coal operations. This emphasises that rehabilitation is a critical component of overarching mine planning and management, from project planning through to receipt of a closure certificate. It also highlights the importance of initiating monitoring protocols as soon as land is disturbed, maintaining these until mine-related site impacts have been deemed acceptable to decision-makers.

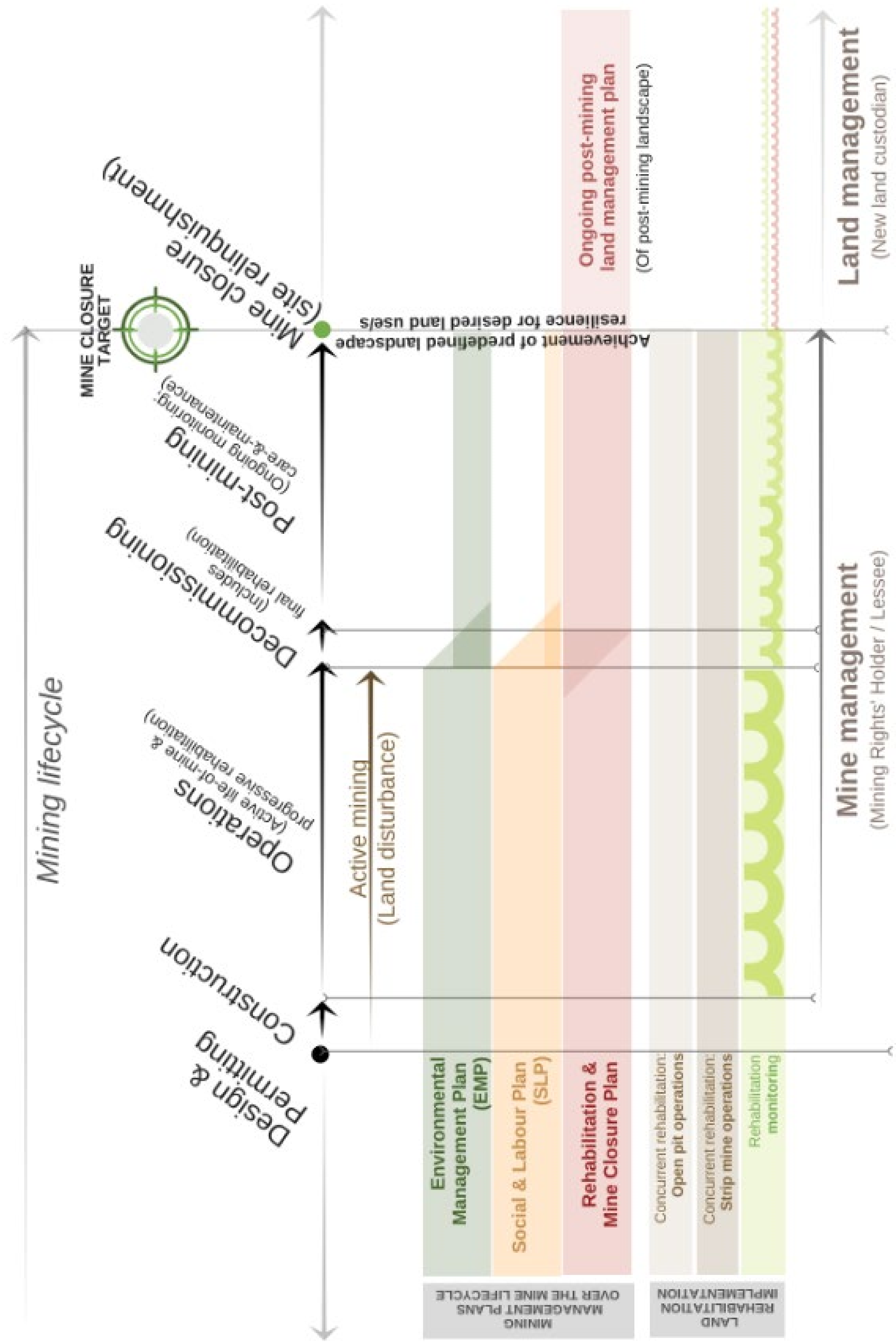


Figure 2: Mining lifecycle highlighting integration of land rehabilitation planning Stages of land rehabilitation

Mining-related rehabilitation should be undertaken progressively, or concurrently, as the mine's operations proceed, initiated from the time of construction. Various stages form part of the rehabilitation process. Figure 3 illustrates these stages, using a dragline operation as an example:

- Topsoil stripping (A);
- Subsoil stripping (B);
- Mining (dragline) (C);
- Spoils levelling (D);
- Subsoil placement and levelling (E);
- Topsoil placement and levelling (F); and
- Fertilising and seeding of soiled areas (G).

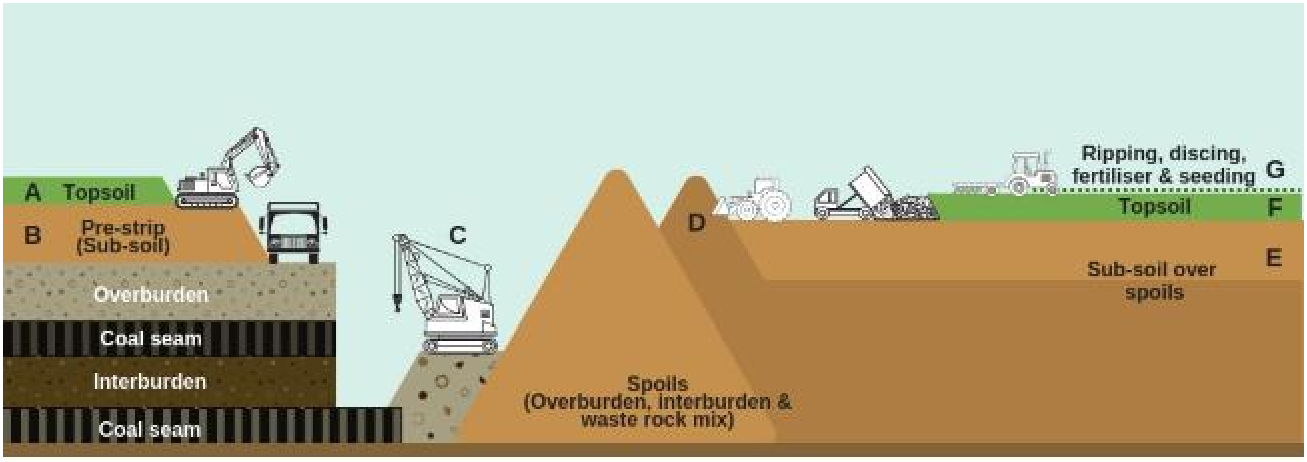


Figure 3: Stages of the land rehabilitation process on a standard strip coal mine

1.3. Land rehabilitation terminology

Much of the terminology around mining-related land rehabilitation is used incorrectly. 'Land capability', 'land use', 'landform', 'rehabilitation', 'landscape' and 'mine closure' are used loosely and sometimes interchangeably. Although the eventual goals may be similar, each term implies a specific action or activity that requires individual planning consideration. This section provides some clarity.

1.3.1 Land capability

Land capability refers the potential of land to support different land uses, and is determined by the physical, chemical and biological properties of the soils. In nature these qualities develop over millennia and are dependent on the type of underlying parent rock, the geographic locality, and climate. On rehabilitated land, the desired land capability is reinstated by re-creating the key fundamentals of what defines land capability (e.g. soil type, soil depth, soil texture, soil density, soil chemistry, topographic slope, and soil microbiology).

All land uses require a specific land capability or suite of land capabilities for successful implementation. The South African Department of Agriculture, Forestry and Fisheries (DAFF) makes provision for eight land capability classes[4 & 5]. The land capability classification is an expression of the effect of physical factors for crop suitability and production, for grazing, for forestry and for wildlife, without damage to the soil resource.

In contrast, the mining industry in the RSA makes provision for four land capability classes – arable land, grazing land, wilderness land and wetland[6]. Although more simplistic, the four classes incorporate features of other systems, notably some of the criteria for identifying prime farmland developed by the soil conservation service of the United States Department of Agriculture (USDA)[7].

The criteria for identifying *pre-mining land capabilities* are each presented in the form of an eliminating key (Table 1). It must be emphasised that the capability or potential of the land, and not its present or past use, is the basis for allocating land to a particular land capability category. Furthermore, the assessment of land capability is an interpretive exercise using the raw data on soils and topography assembled during the pre-mining data collection period.

The *post-mining land capability* criteria use pre-mining land capability as the starting point. In the final analysis, a mined-out area – less that occupied by spoil from the initial boxcut and by final voids – should have the same relative proportions of arable, grazing and wetland land as were present in the affected area before commencement of mining. It is noted that the operator of a mine cannot be required to upgrade the original capability of the land during rehabilitation. However, the operator is expected to ensure that mining operations do not unnecessarily reduce land capability. Agricultural land capability assessments done prior to mining will provide the primary basis for determining the standard of rehabilitation to be attained in any particular instance. The pre-mining land capability assessments should be used to determine post-mining land capability targets, and to inform the rehabilitation plan. The original spatial distribution of land capability units does not have to be replicated and may be improved on, for example, by engineering arable land into consolidated blocks where these might originally have occurred in a fragmented pattern.

[4] *http://www.agis.agric.za/agisweb/ landcapability.html* - accessed 16 September 2018.
[5] It is noted that at the South African DAFF has recently refined the eight land capability classes and associated selection criteria. However, as many of the coal mines' environmental commitments are already based on the noted four land capability classes, these have been retained for use in this Guideline.
[6] Chamber of Mines (1981): Guidelines for the Rehabilitation of Land Disturbed by Surface Coal Mining in South Africa.
[7] United States Department of Agriculture (2011): National Agricultural Land Evaluation and Site Assessment Handbook.

Table 1: Land capability classes and associated pre-mining and post-mining classification criteria against which rehabilitation objectives should be set

<table>
<tr><th colspan="2" rowspan="2">Land capability class</th><th colspan="2">Classification criteria</th></tr>
<tr><th>Pre-mining</th><th>Post-mining</th></tr>
<tr><td>I</td><td>Wetland</td><td>• Usually a water table present at shallow depth in the soil (vleis, swamps, marshes, peatbogs, etc.).
• A diagnostic[8] organic (O) horizon at the surface.
• A horizon that is gleyed throughout more than 50 percent of its volume and is significantly thick, occurring within 750 mm of the surface.</td><td>• Soil depth >250 mm.
• Specific wetland soil used, as stockpiled from pre-mining delineated wetland areas.</td></tr>
<tr><td>II</td><td>Arable</td><td>• Does not qualify as wetland.
• Has soil that is readily permeable[9] to the roots of common cultivated plants throughout a depth of 750 mm from the surface.
• Soil pH value between 4,0 and 8,4.
• Electrical conductivity (EC) of the saturation extract less than 400mS/m at 25°C, and an exchangeable sodium percentage less than 15 through the upper.
• Soil depth of ≥750 mm of soil.
• Permeability of at least 1,5 mm per hour in the upper 0.5 m of soil.
• <10 percent by volume of rocks, or pedocrete fragments larger than 100 mm in diameter in the upper 750 mm of soil.
• Slope (in percent) and erodibility factor[10] (K) such that their product is less than 2,0.
• Occurs under a climate regime which permits, from soils of similar texture and adequate effective depth (750 mm), the economic attainment of yields of adapted agronomic or horticultural crops that are at least equal to the current national average for those crops.
• Is either currently being irrigated successfully or has been scheduled for irrigation by the DAFF.</td><td>• Soil depth > 600 mm
• Soil material must not be saline or sodic.
• Slope (%) will be such that when multiplied by the soil erodibility factor K, the product will not exceed 2,0.
• For typical coal fields' soils, slopes must be flatter than 1:14, and free draining.</td></tr>
<tr><td>III</td><td>Grazing land</td><td>• Does not qualify as wetland or as arable land.
• Has soil or soil-like material, permeable to the roots of native plants, that is more than 250 mm thick and contains less than 50 % by volume of rocks, or pedocrete fragments larger than 100 mm diameter.
• Supports or is capable of supporting a stand of native or introduced grass species or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.</td><td>• Soil depth ≥ 250 mm
• Slopes between 1:7 and 1:14</td></tr>
</table>

8 Macvicar et al (1977): Diagnostic horizons and materials referred to in this discussion are as defined for the South African soil classification system.

9 Materials and diagnostic horizons which are not readily permeable and should therefore not be encountered within 0.75 m of the surface include hard rock, pedocretes (calcrete, ferricrete and silcrete) in sheet form, any soil material that is strongly cemented, dorbank, fragipans and diagnostic hard plinthic, gleycutanic and prismacutanic B horizons.

10 The erodibility factor (K) can be obtained from the nomograph published in Wischmeier, Johnson and Cross (1971)

Land capability class		Classification criteria: Pre-mining	Classification criteria: Post-mining
IV	Wilderness land	• Land that has little or no agricultural capability by virtue of being too arid, too saline, too steep or too stony to support plants of economic value. • Its uses lie in the fields of recreation and wildlife conservation. It does, however, also include watercourses, submerged land, built-up land and excavations. • Defined by exclusion, namely: land that does not qualify as wetland, arable land or grazing land.	• Soil depth between 150 – 250 mm.

A detailed evaluation of land capability is probably the most important component of the pre-mining land inventory because it provides the only objective basis for establishing the post-mining land use capability targets. It is not sufficient to state merely that land will be rehabilitated to an 'agricultural capability'. This is far too wide a concept and is susceptible to too many different interpretations for the term 'capability' to be left unqualified. Similarly, in the undisturbed state, land capability may vary extremely widely, often over short distances, as a function of soil characteristics, topography, surface and near-surface geology, and vegetation. Some classification of capability is therefore essential.

1.3.2 Landform

Landform is a natural feature of the solid surface of the earth. Landforms together make up a given terrain, and their arrangement in the landscape is known as topography. Landforms are categorised by characteristic physical attributes such as elevation, slope, orientation, stratification, rock exposure, and soil type[11]. Landforms in a rehabilitated mining landscape generally refer to the back-filled (or unfilled) pits and designed and re-profiled surfaces of the remaining overburden dumps / facilities. The shaping of the mine's larger 'generally disturbed surface areas' (such as reclaimed haul roads, infrastructure footprints and secondary disturbance areas) are also considered part of an operation's overall landform design.

1.3.3 Rehabilitation, remediation, reclamation, regeneration

Rehabilitation is the transformation of land disturbed from its original condition, (such as through mining), to a new and beneficial condition. From a mining perspective, rehabilitation of disturbed land results in the

[11] https://en.wikipedia.org/wiki/Landform - accessed 16 September 2018.

return of the land to a stable condition capable of supporting permanent productive use as directed by a mine plan and post-mining land use plan.

Globally, the term rehabilitation is often interchanged with those of remediation, restoration and/or reclamation. *Remediation* is the environmental clean-up of land and water contaminated by organic, inorganic or biological substances, and is a term commonly used in industrial-related activities such as processing and manufacturing plants. *Restoration* is considered the artificial acceleration of the processes of natural succession by putting back the original ecosystem's function and form. *Reclamation* is the overarching process of converting derelict land to usable land and may include engineering as well as ecological solutions. Restoration, rehabilitation and remediation are all aspects of reclamation.

Experience indicates that establishment of restored systems (*original* ecosystem function and form) is often impossible on mine sites. Hence, as this Guideline only focuses on the 'land' component of rehabilitation (and not all aspects of reclamation) and assumes an opencast coal mine site will never be fully 'restored', the term rehabilitation is maintained throughout.

The concept of *regeneration* is fast becoming a driver for land rehabilitation objectives and implies consideration of broad socio-economic and environmental aspects within rehabilitation planning so that the rehabilitated post-mining landscape can return economic and ecological benefits to the post-mining land users. Once again, this term is an overarching concept, like reclamation, and will need to be used as part of setting eventual value-generating mine site relinquishment criteria. It should not, however, enable downgrading of site-specific rehabilitation principles in exchange for perceived (unachievable/unrealistic) socio-economic benefits.

1.3.4 Land use

Land use is the way land is used by humans for a defined purpose and may comprise one or more land uses. In most instances, one landscape can support numerous land uses within the constraints of land capability, creating a multifunctional landscape. *Land use planning* is the systematic assessment of potential alternatives for land use, under specific economic and social conditions, that leads to the selection and adoption of the best (sustainable) land use options[12]. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. Ultimately, land use planning involves anticipation of the need for change as well as reactions to it.

The term *landscape* is also used in this Guideline to describe the larger geographical footprint of the land rehabilitation planning area. It encompasses the land capability and land use/s, from ecological, social, financial and aesthetic perspectives.

[12] International Council on Mining and Metals (2011): The role of mining and metals in land use and adaptation

1.3.5 Mine closure

Mine closure is the point at which eventual sign-off of the rehabilitated land to a new/alternative owner is achieved. Mine closure is the ultimate goal. It is the last stage of the mining lifecycle and is the point at which site monitoring has demonstrated that the predefined land capabilities on the rehabilitated land, aligned to the agreed-on relinquishment criteria, have been achieved.

Figure 4 illustrates the interrelationships between land capability, rehabilitation and land use within the rehabilitation planning discipline, towards achieving a sustainable post-mining landscape. The spatial and temporal planning on a mine site, and the implementation of rehabilitation and land use-related activities, change continually throughout the mining lifecycle. This implies that amendments, refinements or corrective action should be an integral aspect of this planning, improving the trajectory towards success as new site knowledge and learnings becomes available.

Rehabilitation activities should be devised as part of upfront mine planning and should be implemented as soon as site disturbance (construction) starts and should be maintained throughout the operational and decommissioning periods. These activities remain even more pertinent to the post-mining (monitoring and maintenance) period, during which successful implementation of the pre-defined land use/s can be demonstrated. EMPs, rehabilitation- and mine closure plans are ‘living’, changing tools, aligned towards a common goal – eventual site relinquishment of an ecologically functioning and socially acceptable landscape asset for future generations.

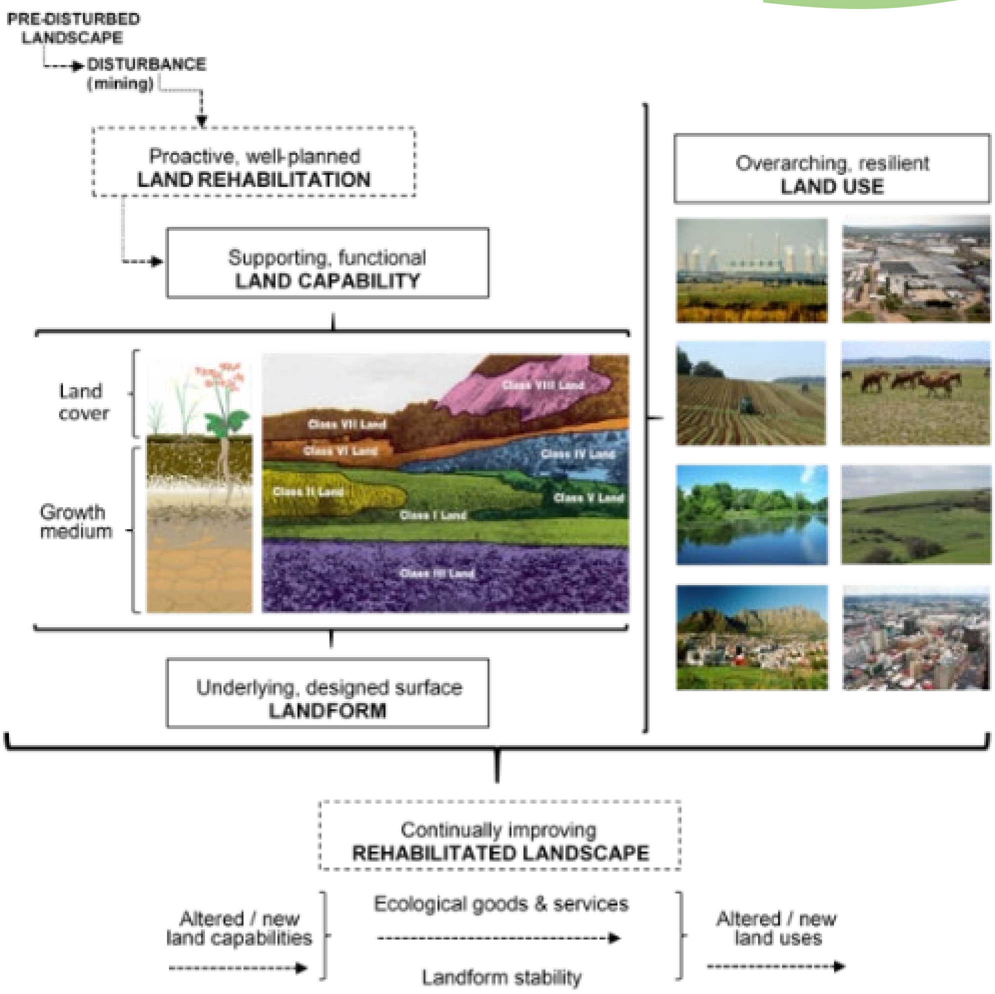


Figure 4: Inter-relationships between land capability, land use, rehabilitation and mine closure, as a function of planning towards a sustainable post-mining landscape

NOTE:

Refinements to a site's rehabilitation plans and implementation programs should allow for adaptation to changing local socio-economic and biophysical (including ecological) conditions. These refinements must not be seen as an opportunity to 'manage operational financial constraints' or downgrade EMP commitments!

APPENDIX

Appendix A:
Land rehabilitation terms and abbreviations used in this Guideline

1.4. Key land rehabilitation aspects – what is the target?

Mining has indisputable socio-economic, physical, and biophysical impacts on soil, water, air, ecological habitats and regional landscapes. The scale and severity of the site-specific impacts drive the focus of the mine's rehabilitation objectives.

Pre- and post-mining landscapes often differ dramatically from each other, primarily in terms of surface and sub-surface soil (pedological) structure, land capability, resource (soil, vegetation and water) availability, as well as human settlement-related infrastructure. Ultimately, surface mining always involves a twofold change in land use, one from a pre-mining landscape to a mining landscape, and then secondly from a mining landscape to a post-mining landscape (Figure 5).

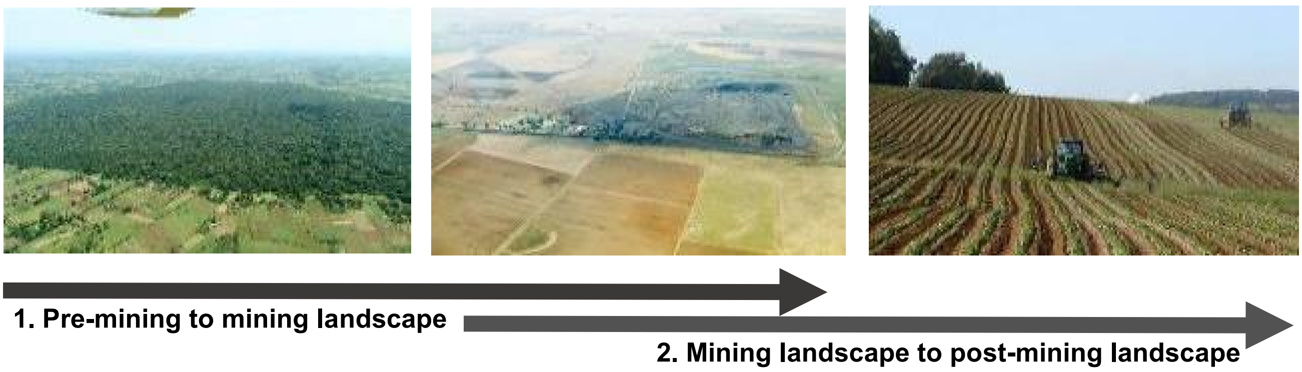


Figure 5: Evolution of the surface mining landscapes – pre-mining to mining, and then from mining to post-mining

In order to suitably identify site-specific rehabilitation actions, the post-mining landscape (rehabilitation targets) needs to be defined.

For example, an agricultural focus aims at securing suitable land capabilities that can contribute towards local food production, either through cropping or livestock grazing. A hydrological rehabilitation focus aims at ensuring local and regional catchment integrity, towards limiting water resource contamination, improving recharge to affected aquifers, and providing usable water for future downstream users. An ecological rehabilitation focus aims at reinstating and improving ecosystem goods and services on rehabilitated land, by reinstating and improving ecological functionality of both terrestrial and aquatic habitats. More recently, and as driven by global community needs and demands, the focus of mining rehabilitation and closure planning is turning to addressing social (community) enhancement and empowerment opportunities. The latter is strongly interlinked with the need to create alternative livelihoods for neighbouring (mining-impacted) communities, whilst ensuring that the post-mining land use opportunities identified are sustainable.

Once these overarching rehabilitation targets have been set, specific rehabilitation actions can be devised for the following key land rehabilitation aspects:

- Surface landform design and physical profiling;
- Soil stripping, stockpiling, and replacement[13];
- Soil amelioration;
- Revegetation; and
- Removal or re-use of existing surface infrastructure.

This Guideline provides a knowledge base for each of these aspects, aiming to assist land practitioners develop site-specific rehabilitation targets and associated implementation actions.

2. LEGISLATIVE REQUIREMENTS

2.1 Intent of this section

The intention of this section is to draw together some of the more important requirements which, explicitly or by implication, affect rehabilitation and have played a part in determining the scope and extent of this Guideline.

This Guideline assumes that land rehabilitation practitioners are familiar with the general legislation applicable to South African mining-related land rehabilitation practices. To this end details of the statutory global context and applicable South African legislation is found in the supporting appendices.

Legislation sets general requirements that must be met without necessarily specifying the means to meet these requirements. This Guideline attempts to articulate legal obligations in terms of practical procedures, operations and performance standards. It highlights the key areas of South African legislation that should inform the development of a mine site's closure and rehabilitation plan, and the factors that must be taken into consideration.

2.2 Development of the legal realm related to rehabilitation and closure

In South Africa, the Mineral and Petroleum Resources Development Act, No. 28 of 2002 (MPRDA) came into effect on 1 May 2004. The MPRDA is administered by the Department of Mineral Resources (DMR), who is the authority for mining right authorisation and closure certification. During 2014, the South African government implemented the One Environmental System. This resulted in collaborative governance between the DMR and the Department of Environment Affairs (DEA) to provide aligned legislation so that environmental impacts from mining and other projects would be minimised and effectively managed. The DEA's National Environmental Management Act, No. 107 of 1998 (NEMA), and its associated regulations, stipulate the approach to conducting mining and other EIAs, and is the primary piece of legislation requiring EMPs for managing environmental impacts. A key aim of the One Environment System is to ensure these activities are controlled under the same system, treated in a similar manner, and thereby are streamlined across environmental authorisation-permitting processes.

[13] Materials balancing is essential for both landform profiling and soils management and is addressed as such in this Guideline.

In 2015, all environmental-related provisions of the MPRDA were repealed and provided for in the amendment to the NEMA, as implemented on 08 December 2014 (National Environmental Management Amendment Act, No. 62 of 2008). This implies that the closure of a mine requires an application for Environmental Authorisation, supported by a closure plan and environmental management programme (Closure EMPr), the contents of which are stipulated in the environmental impact assessment (EIA) Regulations GN R.983.

In addition, NEMA's General Notice Regulation (GNR) 1147 "Regulations pertaining to the Financial Provision for Prospecting, Exploration, Mining or Production Operations" (Financial Provisioning Regulations) was promulgated on 20 November 2015. The intent of the regulations is important to ensure operations align correctly in their execution to comply with the regulations. The intent is fourfold, as follows:

- To establish the obligation of an applicant and holder to plan, manage and implement procedures and requirements to remediate and rehabilitate environmental damage caused by mining operations;
- To regulate the manner in which an applicant or holder is to determine, provide, set aside, maintain and manage financial security for undertaking progressive rehabilitation, decommissioning, closure and post closure activities associated with mining operations;
- To identify the circumstances under which the Minister may use the financial provision set aside to affect the obligation of the holder to remediate and rehabilitate negative environmental impacts and environmental damage; and
- To ensure that the State does not become liable for those costs which should be covered by a holder and to facilitate environmentally sustainable mining.

2.3 Regulations pertaining to the financial provision for rehabilitation and closure

The Financial Provisioning Regulations provides detailed content requirements for operational rehabilitation and closure planning and provisioning with a set of specific templates that is prescribed for plans, bank guarantees and trust fund contents.

It requires a prospecting, exploration, mining or production rights holder to compile and update (annually) the following three plans:

- Annual rehabilitation plan;
- Final rehabilitation, decommissioning and closure plan; and
- Environmental risk report (including post-closure residual and latent risks).

The intent of this reporting regime is to increase granularity, accurate provisioning and accountability for successful post closure landscapes. The proponent must provide detailed information so that the costs associated with the management, rehabilitation and remediation of any potential environmental impacts arising from mining and related activities can be determined. This includes financial provision for closure at the operation's envisaged end of life, as well as for any operation-related residual environmental impacts that may become known in the future (post-closure). Cost calculations and financial provision for different authorisations and amendments may need to be indicated to ensure the full scope of expanding operations are addressed. The financial provision, for costs calculated, must guarantee the availability of sufficient funds. The proponent is required to provide funds for the costs of annual rehabilitation from the operational budget of the company and set aside funds, using the methodology conforming to the requirements identified for new operation or existing operation as per regulation appendices.

Once the annual rehabilitation plan, final rehabilitation, decommissioning and closure plan, and environmental risk report have been compiled, and the associated costs have been determined, the plans and cost estimates need to be reviewed and audited by an independent financial auditor. In terms of the Financial Provisioning Regulations, the three plans need to be updated on an annual basis and the cost estimates adjusted accordingly, based on progress made with concurrent rehabilitation, any new areas of disturbance that have been opened up, as well as any notable changes or refinements that have been made to the mine plan (see Figure 6) [14].

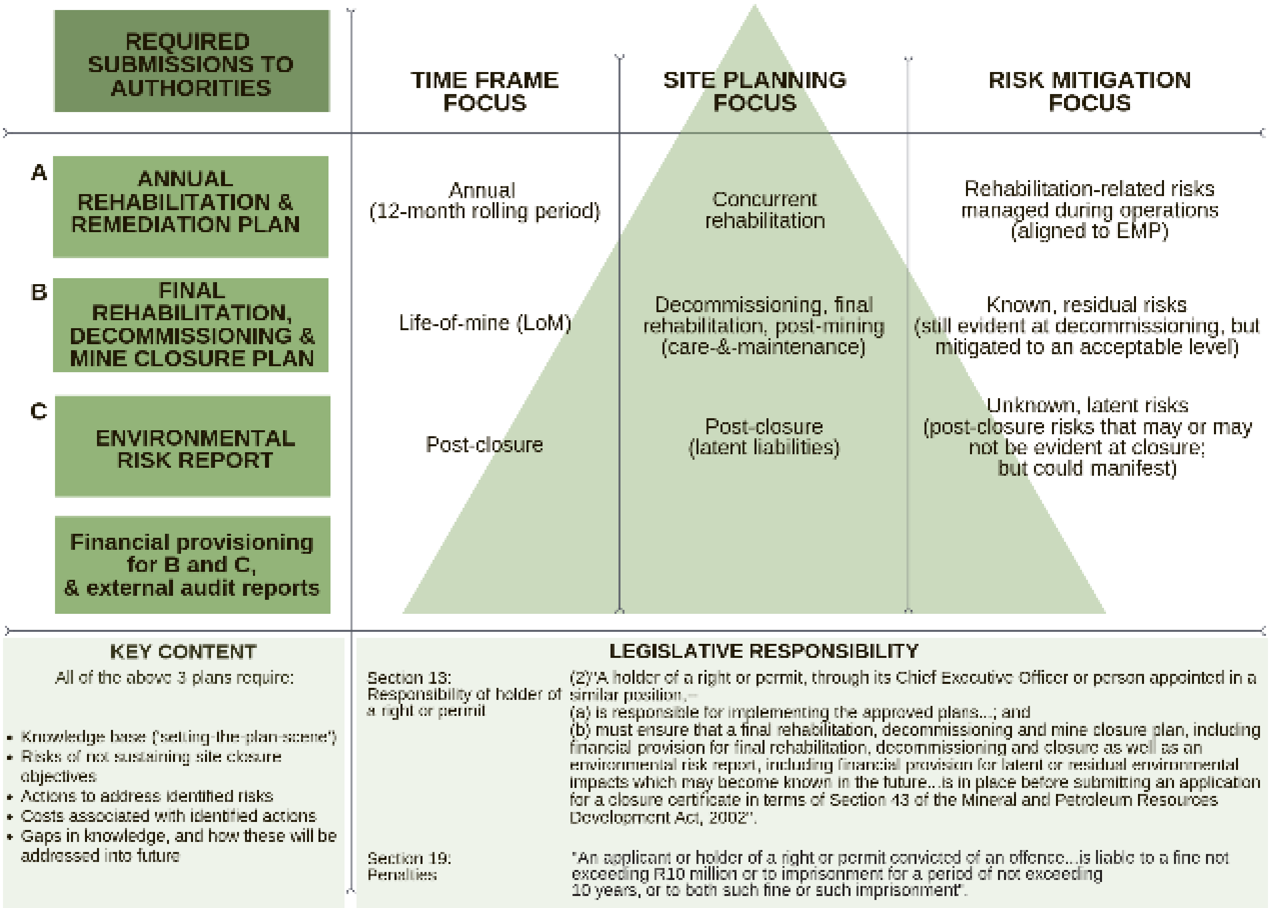


Figure 6: Rehabilitation planning requirements for the NEMA Financial Provisioning Regulations (currently GNR1147, 20 November 2015)

[14] It is noted that at the time of compilation of this Guideline, NEMA's GNR1147 is undergoing refinement, with the amendment expected to be promulgated in 2019.

2.4 Other legislation determining rehabilitation and closure compliance

The Department of Water and Sanitation (DWS - previously referred to as the Department of Water Affairs), via the National Water Act, No. 36 of 1998 (NWA), governs the way national water resources are managed. This Act specifies the 'Duty of Care' principle, that "A duty is imposed on the owner of land, a person in control of land or a person who occupies or uses the land to take all reasonable measures to prevent the pollution of a water resource from occurring, continuing or recurring". In addition, the NWA's Regulation 704 on the "Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources" underpins the governance expectation on an operation to adequately manage clean and dirty water impacted by, and/or generated and emanating from, its site.

Supporting environmental management acts (SEMAs) underpin execution of NEMA. Specifically, Section 17 of the National Environmental Management Waste Act, No. 59 of 2008 (NEM:WA) requires the reduction, re-use, recycling, recovery, treatment and disposal of waste; the National Environmental Management Biodiversity Act, No. 10 of 2004 (NEM:BA) requires dedicated eradication and management of listed invasive flora and faunal species on rehabilitated land; and the National Environmental Management Air Quality Act, No. 39 of 2004 (NEM:AQA) focuses on an operation's requirement to prevent and manage air pollution. The SEMAs provide legislative requirements for both the operational, post-mining and post-closure landscapes.

The Conservation of Agriculture Act, No. 43 of 1983 (CARA), as promulgated and implemented by the Department of Forestry and Fisheries (DAFF), governs the management and restoration of national land resources. This Act focusses on maintaining productive land capabilities through restoration of disturbed (eroded) land and managing invader plant species. DAFF officials are consulted during the public review process during the compilation of a mine's EIA/EMP, prior to issuance of environmental authorisation and a mining right, but DAFF has limited influence on the selection and/or improvement of suitable post-mining land use/s. However, the DAFF is in the process of promulgating the Preservation and Development of Agricultural Land Act (PDALA[15]). The purpose of this Act appears to focus on the custodianship of "agricultural land" and, inter alia, to regulate the subdivision and rezoning of high potential cropping land and medium potential agricultural land, and to provide for the proclamation of so-called protected agricultural areas. Furthermore, in terms of Section 3 (of the draft Bill), the custodianship of designated "agricultural land" will be assigned exclusively to the DAFF. In Section 3(2), DAFF confirms that, acting through the National Minister or MEC's at provincial level, DAFF will "approve, reject, control, administer, and manage" any rezoning or subdivision of agricultural land. This could impact the authorisation of future mining rights located on any remaining high potential cropping land under which much of the country's remaining coal reserves are located, and on the amendment of predefined post-mining land uses.

[15] It is noted that at the time of compilation of this Guideline, PADLA is expected to be promulgated in the near future.

From an urban land use planning perspective, the Spatial Planning and Land Use Management Act, No. of 2013 (SPLUMA) places the management of local land use matters in the hands of the local government. The Act requires that each Local Municipality must, after public consultation, prepare, adopt and implement a land use scheme (LUS), consistent with any existing Municipal Spatial Development Framework (SDF), within five years of the Act being brought into effect (end-2018). Importantly, SPLUMA determines that the land use-related decisions of the local authority cannot be overturned at the national level except in the case of agricultural land. This could have implications for operations when applying for amendments to predefined post-mining land use/s and/or the transfer of liabilities, assets or Title Deeds.

The National Heritage Resources Act, No. 25 of 1999 (NHRA) places specific focus on ensuring there is no altering or demolition of structures older than 60-years and final comment may be required before demolition of old mining works.

The Mine Health & Safety Act, No. 29 of 1996 (MH&SA) requires that "the owner of a mine not being worked, but in respect of which a closure certificate…has not been issued, must take reasonable steps to continuously prevent injuries, ill-health, loss of life or damage of any kind from occurring at or because of the mine". This places certain occupational obligations on the operation when in temporary cessation or rehabilitation phase.

A detailed description of the above key legislation is provided in Appendix B.

APPENDIX

Appendix B:
Key South African land rehabilitation-related legislation

3. PLANNING & DESIGN FOR LAND REHABILITATION

3.1 <u>The business case for successful rehabilitation</u>

Rehabilitation is an expensive business, which can account for as much as 10% of mining costs in certain circumstances. As most of these costs are usually incurred after a significant portion of mining has been completed, some form of guarantee is usually required by the DMR to ensure that sufficient funds will be available to meet the rehabilitation liability at any point in the life of the mine.

Mining methods, minerals processing and management technologies have also developed to a high level of sophistication and efficiency. It is often possible to reduce environmental impacts through the implementation of relatively simple, and low cost, scientific and engineering technologies during the initial stages of project construction and operation. Conversely, the cost of retroactive installation of environmental control technologies at later stages in the project lifecycle is likely to be prohibitive[16]. The same principle holds true in terms of land rehabilitation, as the financial cost of 'back-engineering' to facilitate or enable certain rehabilitation goals late in the lifecycle of a mine is likely to be high. Failure to adequately consider rehabilitation needs during initial planning may therefore have serious financial repercussions for mines, more so in instances where negative press coverage and public dissatisfaction resulting from undesirable long-term conditions arise.

Mine closure and rehabilitation designs need to form part of the feasibility study phase of a mining project. Many decisions around eventual site closure can already be made during the concept and pre-feasibility stages of the project. These include undertaking geochemical modelling to see if acid mine drainage (AMD) or saline mine drainage (SMD) can be expected, and what levels of water contamination and volumes of contaminated water could be expected (indicating what type of water treatment or water management will be needed) after closure. Initial risks related to post-mining topographies, land use plans and recreation of sensitive habitats (e.g. wetlands) can also be highlighted during the early project phases. Of critical importance is having the full environmental cost of mining included in the net present value (NPV) calculations in the financial models for the project, particularly in the feasibility stage when the project is evaluated for financial viability. This full costing for managing environmental impacts must include provision for adequate aftercare, contingencies and water management costs for the post-closure phase after site.

The development of water management facilities, either as a dedicate mine plant or as a regional initiative, needs to be incorporated into a mine's long-term business, risk and financial planning

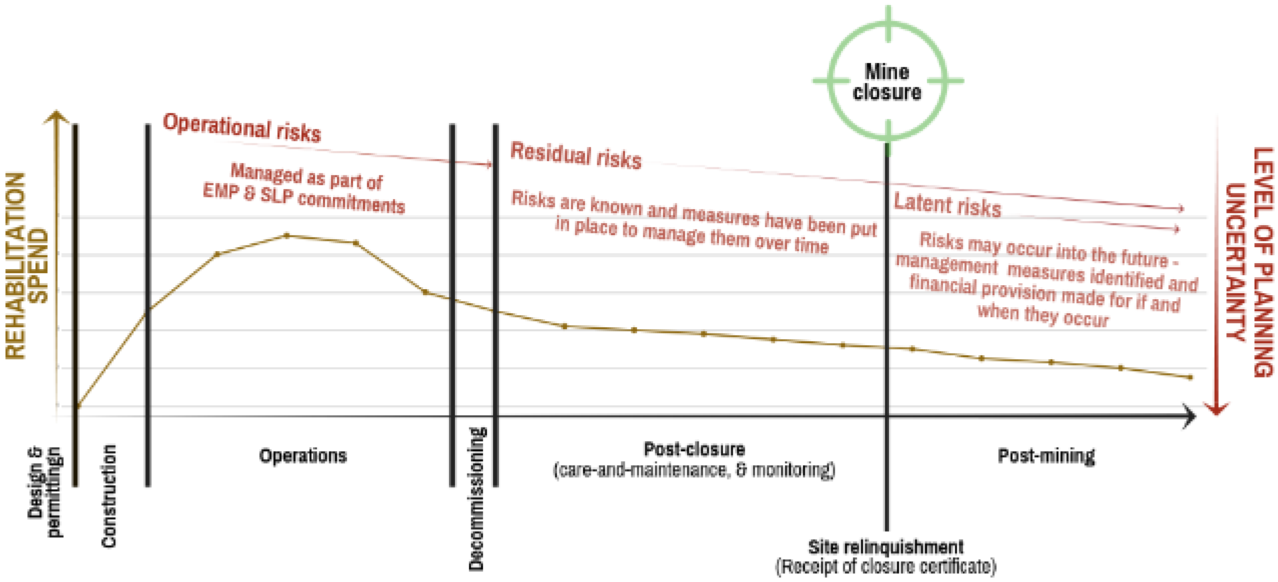
The question is, then, how will the costs of rehabilitation be funded if the mine closes prematurely, either due to mining challenges or to decreased value of the product (market pressures)? There are a number of financial vehicles that can be used to meet the cost of rehabilitation. However, for all of them, there needs to be an accurate estimate of the cost of rehabilitation and of when that rehabilitation is going to be done.

Integrated and aligned rehabilitation and mine planning is hence required to guide operational development and reduce the level of uncertainty around closure-related site knowledge, concurrent rehabilitation practices, and the expectations related to long-term social and environmental liabilities. Site knowledge, in the form of a clear post-mining land use goal, informative specialist studies, and trend analysis from monitoring of key indicators can greatly reduce planning and implementation uncertainties. As uncertainties manifest or develop over time, human and financial capital is required to reduce these

[16] Morrey, D.R. (1999): Integrated planning for environmental management during mining operations and mine closure. Minerals and Energy 14(3). pp 12 -20.

uncertainties. Hence, limiting these closure-related site uncertainties directly minimises the ongoing long-term financial provision required to manage or mitigate the rehabilitated landscape.

In addition, closure-related implementation schedules and the quality and effectiveness of concurrent rehabilitation activities help mitigate long-term risks potentially associated with the rehabilitated site, as well as reducing the potential negative consequences of such events if they still occur. Ultimately, integration of rehabilitation and closure planning from project conceptualisation to final closure enables an operation to limit the possible impacts from poor rehabilitation and to reduce the risk of unwanted impacts after closure. In turn, integrated planning reduces the financial provision required to manage mining-related impacts and risks (Figure 7).



Alignment of the management actions to prevent or control a site's biophysical impacts across the mining lifecycle is therefore critical to long-term business resilience.

Figure 7: Rehabilitation planning across the life-of-mine, indicating how appropriate planning can reduce closure-related risks and reduce/minimise financial provision required to manage residual and latent impacts

3.2 Applying a risk-based approach

Aside from the obvious biophysical impacts posed by a mine, previously mined areas can also pose several long-term risks. These can be residual risks that will likely remain post-mining and require management into perpetuity, or latent risks that manifest in the rehabilitated landscape post-closure, often many years after site relinquishment. These have obvious restrictions on the implementation of identified post-mining land uses, and the associated manner in which rehabilitation activities are undertaken.

Risk-based management identifies the actions required to control and mitigate environmental risks, facilitating the sustainable use of the area in the future and reintegrating it into the local landscape[17]. A formal and effective critical risk analysis of the rehabilitation actions identified for a site is required to assess how effective the defined actions might be, and whether sufficient financial and other resources are available to ensure proper execution of the actions[17]. In this way, management decision-making would be informed by an understanding of the risk posed by site uncertainties and potential environmental liabilities.

Mines, together with the authorities, should adopt such a risk-based approach to provide the necessary confidence that the mine has accurately predicted its long-term impacts and has made the necessary resources and financial provisions available to address these[18]. Such an approach is foreseen to have the following implications for a site's mine- and rehabilitation planning[18]:

- Conventional planning and commissioning of new developments, and the day-to-day environmental management actions, need to focus on the identification, quantification and management of real environmental risks, as opposed to perceived risks.
- The mine may have to go beyond minimum legal compliance to be able to adequately address the real risks preventing closure.
- The conventional mine closure cost estimation process, usually dictated by individual role-players' perceptions of risk and the legislation of the day, would have to be adapted to include the real risk concept and become independent of the shifting goalpost syndrome.

3.3 Using the post-mining land use as a rehabilitation target

Defining viable post-mining land uses is essential to setting rehabilitation goals. Poor upfront rehabilitation planning in the past has resulted in a lack of well thought-through post-mining land use/s that ensure restored functionality in the rehabilitated landscapes.

The following key factors motivate the need for dedicated post-mining land use planning:

- Early identification and possible upfront retrofitting of usable infrastructure that could have a beneficial post-mining re-use potential. This includes brick buildings, plant and workshops area, water- or waste pipelines, pumps, treatment facilities, etc.;
- Using the defined post-mining land use to identify suitable rehabilitation measures that will prevent or manage long-term rehabilitation risks. This includes an appropriate cover design over backfilled spoils to limit water ingress, placement of water supply boreholes away from predicted contaminant plumes, etc.;

[17] Taveira, A.L.S. & Sanchez, L.E. (2016): A risk-based framework for managing mine closure. 24th World Mining Congress, Brazil – 2016.

[18] Swart, *et al* (1998): Environmental risk assessment as the basis for mine closure at Iscor Mining. The Journal of The South African Institute of Mining and Metallurgy, January/February 1998.

- Determining if the rehabilitated landscape could offer the same or higher value to remaining communities post-mining. This may be in either monetary value or in the essential ecosystem goods and services that the rehabilitated land will provide and on which the surrounding communities will depend;
- Optimising rehabilitation to deliver required long-term ecosystem functions such as flood attenuation, carbon sequestration, water filtration and purification, etc.; and/or
- Early identification of potential next landowners / beneficiaries and associated co-development of land use agreements. This could foster seamless land ownership transition post-closure. (For mines that still have long lifecycles it may not be possible to identify these potential new landowners and/or public private partnerships early on; however, ongoing planning should aim to do so as soon as possible).

3.4 Special attention for sensitive habitats

Land use change is the leading driver of biodiversity loss in terrestrial and aquatic ecosystems and is expected to remain so in the future[19]. A rehabilitated landscape will likely provide an altered or lower valued ecosystem for goods and services (EGS) in comparison to the pre-mining environment.

However, by reinstating functional ecosystems – specifically sensitive systems such as wetlands and conservation habitats, a number of obvious functions can be regained, such as providing feeding, breeding and nesting areas for fauna and creating potential conservation areas for threatened species. Other inherent functions of such areas include flood attenuation, carbon sequestration, water filtration and purification, all of which have a measurable monetary value. As a result, these areas need to be protected to ensure reinstatement and/or maintenance of the essential functions described. Sensitive habitats should form an integral part of mine rehabilitation planning[20].

Rehabilitated wetland on as part of a mine's site-wide rehabilitation planning

Mitigating negative impacts on sensitive ecosystems is a legal requirement for mine authorisation and must take on different forms depending on the significance of the impact and the area being affected. Mitigation requires a proactive approach to planning a development - through considering options in project location, scale, layout, technology and phasing. Firstly, mitigation aims to *avoid or prevent* disturbance of ecosystems and loss of biodiversity, and then, where it cannot be avoided, to *minimise* impacts. Where

[19] Millennium Ecosystem Assessment. (2005): Living beyond our means: natural assets and human well-being. Island Press, Washington, DC.

[20] Hattingh, R. & Bothma, J. (2013): Taking the risk out of a risky business: a land use approach to closure planning. Proceedings of the International Mine Closure Conference. Vancouver, 2013. pp 2 – 7.

impacts are unavoidable and unacceptable, *rehabilitation* is required. As a last resort, *off-setting* any remaining significant residual negative impact should be provided for (Figure 8)[21].

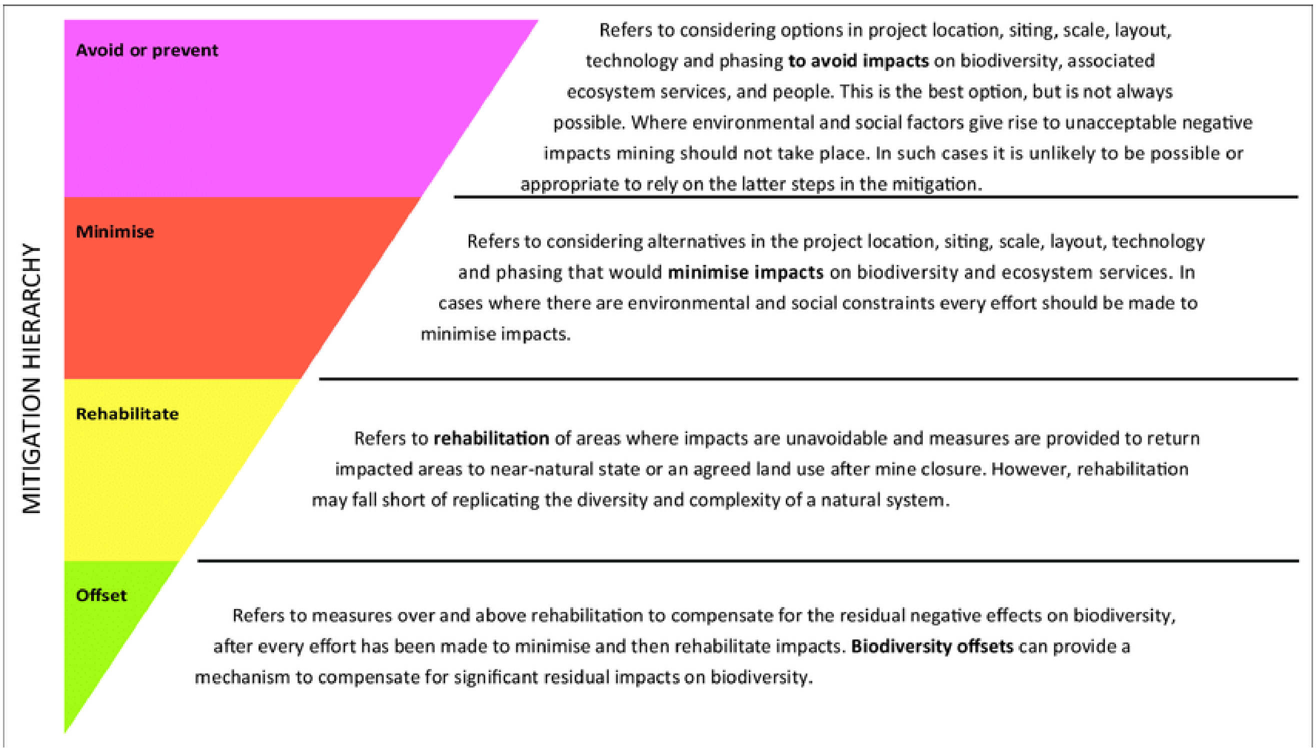


Figure 8: The mitigation hierarchy for dealing with negative impacts on biodiversity

ADDITIONAL RESOURCE

Mining & Biodiversity Guideline:
Mainstreaming Biodiversity into the Mining Sector
(DEA/SANBI, 2013)

ADDITIONAL RESOURCE

Wetland Off-sets:
A Best Practice Guide for South Africa
(DEA/SANBI, 2014)

[21] Department of Environmental Affairs, Department of Mineral Resources, Chamber of Mines, South African Mining and Biodiversity Forum, and South African National Biodiversity Institute (2013): Mining and biodiversity guideline: mainstreaming biodiversity into the mining sector. Pretoria. 100 pages.

3.5 The need for upfront planning

The benefit of early planning for mine rehabilitation and closure is that it reduces both the likelihood and consequence of mining-related environmental impacts, and therefore also reduces potential unwanted operational and post-mining costs.

The advantage of proactive planning is rooted in what may be referred to as the 'time factor'[22]. The shorter the time lapse between the occurrence of environmental damage and its rehabilitation, the lower (in most cases) will be the resources (both human and financial) needed to address the problem.

Rehabilitation planning must evolve throughout the life of the mine, and needs to be reviewed to fit within developmental, ecological, social, and political imperatives as these change[23]. The most critical time in rehabilitation planning is at the mine feasibility stage – this is when the manpower, resources and environmental management systems should be identified to manage the operation's environmental impacts and longer-term liabilities. Rehabilitation can then be undertaken in a planned, timely manner, whilst operational funds and human resources are available to support the rehabilitation activities.

Continuous rehabilitation planning implies an iterative process that extends throughout the life of the operation. With each iteration the level and detail of planning should improve, closing gaps in the site's biophysical knowledge base, refining rehabilitation actions, and improving mitigation of closure-related risks. Accordingly, such planning cannot take place just prior to site decommissioning or, even, every 3- to 5-years.

A dedicated rehabilitation plan needs to be integrated into each operation's site-specific mine plan and should be refined on an annual basis. This process focusses integration across disciplines and management levels. Integration and continual refinement of these plans is the best way to ensure optimised financial expenditure during operations towards achieving a planned post-mining land use that is sustainable in the long-term.

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[22] Warhurst, A. & Noronha, L. (2000): Corporate strategy and viable future land use: planning for closure from the outset of mining. Natural Resources Forum 24. pp. 153-164.

[23] Stacey, J., Naude, A., Hermanus, M. and Frankel, P. (2012): The socio-economic aspects of mine closure and sustainable development: literature overview and lessons for the socio-economic aspects of closure - Report 1. The Journal of The Southern African Institute of Mining and Metallurgy (110). pp. 379-394.

4. DEVELOPING THE REHABILITATION PLAN

This section provides a framework for the compilation of a land rehabilitation plan and highlights the planning drivers covered in the previous section. It also outlines the implementation actions and ongoing monitoring required to achieve the upfront planning targets.

The framework defines key components that should be included as part of the site-specific planning and implementation. Detailed content will be informed by the on-site knowledge base as well as the ongoing monitoring results.

4.1 Rehabilitation plan framework

Figure 9 illustrates the framework that could be used to compile a site-specific rehabilitation plan for a surface coal mine. It comprises the following key steps, aligned to the structure of this Guideline:

1. Planning;
2. Implementing;
3. Monitoring; and
4. Refining; correcting, re-planning.

The above steps are undertaken as a continual process, with each iteration improving on the previous plan. It is critical that rehabilitation planning be an ongoing process, where the plan is refined and improved as an integral part of the annual planning across the operation.

This framework assumes the following fundamental, non-negotiable planning principles:

- All rehabilitation planning will take place in adherence to minimum regulatory compliance requirements. Rehabilitation that does not align to local legislative requirements is deemed inadequate and flawed. Rehabilitation that exceeds local legislative requirements would be deemed good practice and should provide additional post-mining landscape value.
- Any mining-related rehabilitation planning must consider the needs of the stakeholders who will remain in the area after rehabilitation and closure (communities, commercial entities, etc.), as well as stakeholders who will be responsible for the long-term land planning, implementation and custodianship of the post-mining landscape. This ultimately implies a need to restore sustainable livelihoods to the post-mining landscape.

(These ‘underlying non-negotiable’ principles of the framework do not appear as individual components in the framework. All decisions made as part of the individual steps of the framework are assumed to take account of these principles).

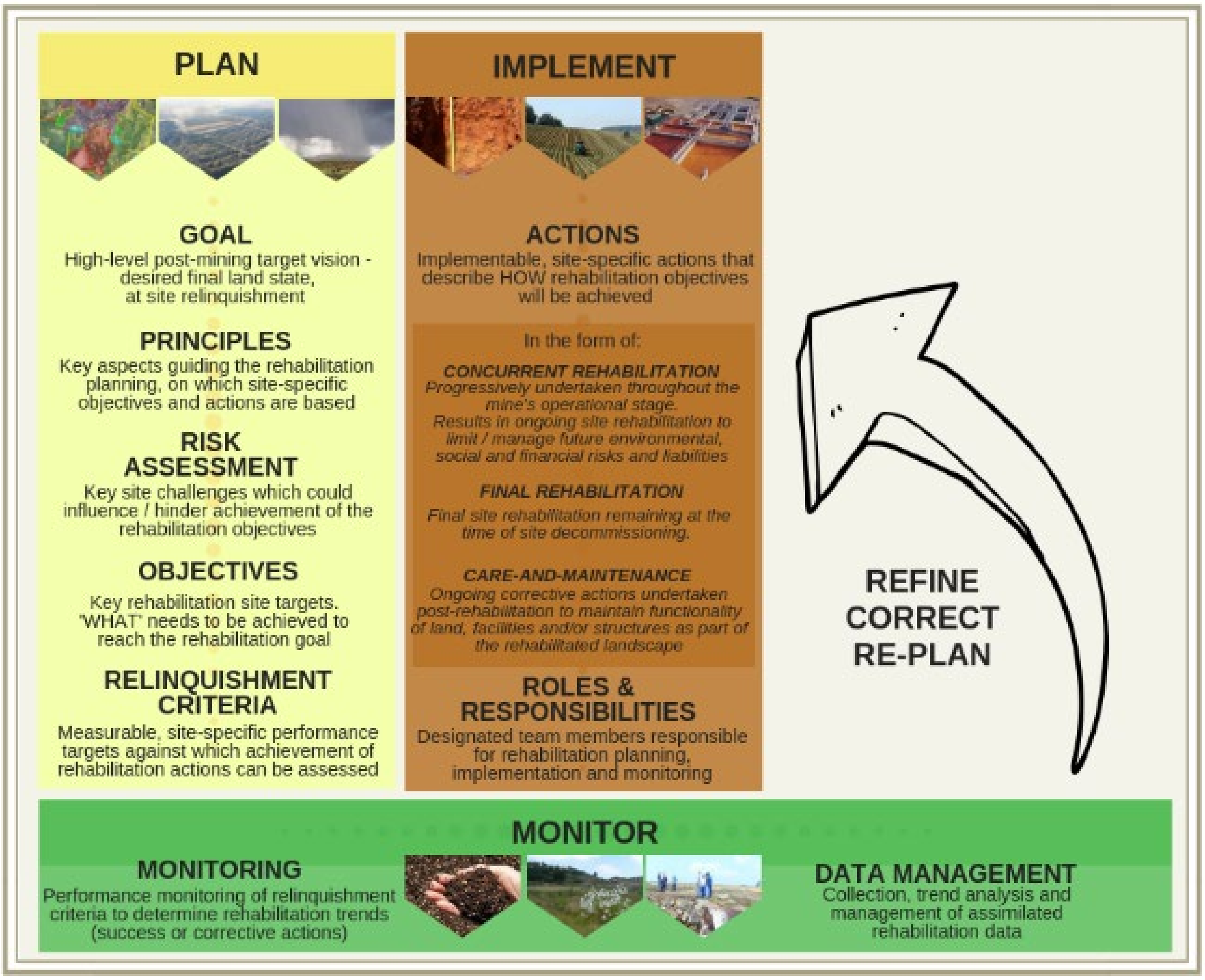


Figure 9: Key framework for a rehabilitation plan

Key aspects of the above components are highlighted below.

4.2 Plan

4.2.1 Rehabilitation goal

A rehabilitation goal is a description of what a mine would like to achieve or accomplish from the closed operation at site relinquishment – the defined level of system resilience, high-level post-mining target state, or vision.

The rehabilitation goal should be realistic, based on the site's physical, environmental and socio-economic assets as defined by available site data and knowledge. It should also provide enough detail to serve as a clear target against which measurable relinquishment criteria can be set.

It is very important that the entire operational team are involved in developing the site's rehabilitation goal. This will ensure buy-in from all levels of management and for the entire team to be working towards achievement of a common outcome.

4.2.2 Rehabilitation principles

Once the overarching rehabilitation goal has been established, the underpinning rehabilitation principles can be defined. A principle is a fundamental 'truth or law' that defines the direction or reasoning for a particular action. For rehabilitation planning, rehabilitation principles are used to define site-specific rehabilitation objectives and actions.

Rehabilitation planning principles should support the following key components of land rehabilitation planning (Figure 10), assuming that these will be undertaken as part of ongoing, concurrent site rehabilitation activities:

- The underlying non-negotiables of regulatory compliance, stakeholder engagement and corporate financial feasibility.
- Land capability, addressing:
  - Landform; and
  - Land use.
- Climate uncertainty.
- Monitoring and adaptive land management.

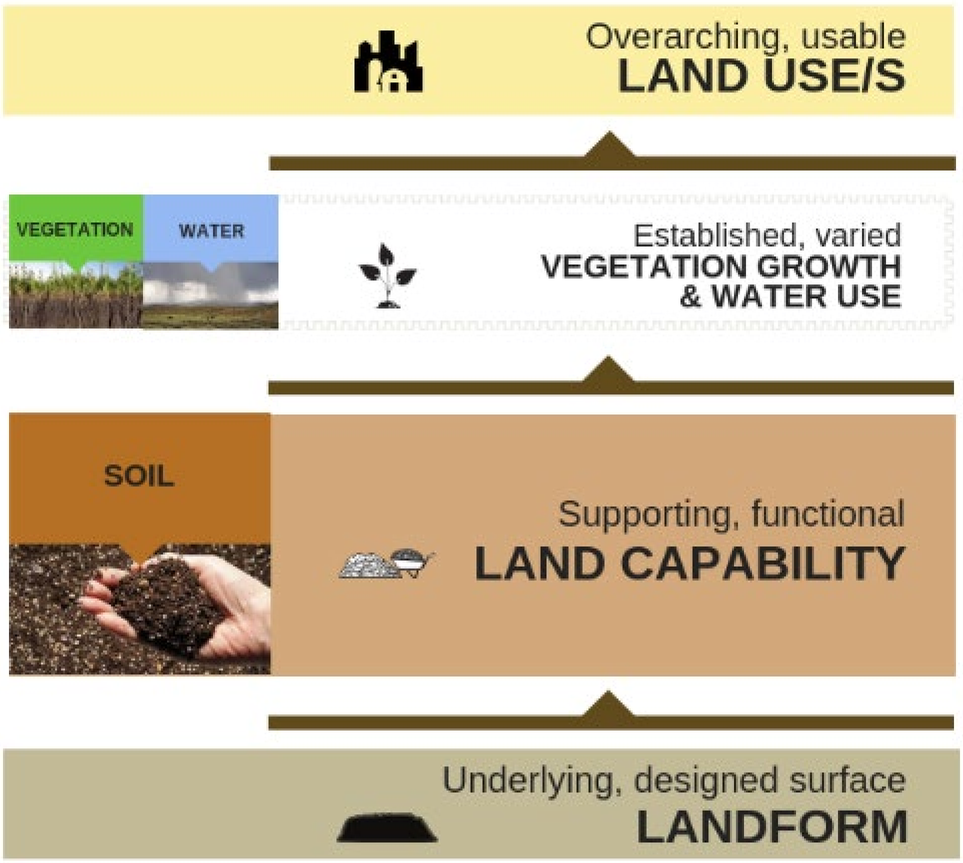


Figure 10: Illustrated key components for surface land rehabilitation

Based on the above, Table 2 summarises possible land rehabilitation principles for these key overarching land rehabilitation components.

Table 2: Key principles for surface land rehabilitation

Component	Rehabilitation principle
Regulatory compliance	• Achieving legal compliance is a minimum for appropriate rehabilitation planning. • Rehabilitation objectives and associated actions will not be in conflict with local legislation and will aim to complement and possibly go beyond legal compliance, where possible.
Concurrent implementation	• Concurrent, progressive rehabilitation will be undertaken throughout the operational stage of mining. • A risk-based approach will be applied to ensure concurrently implemented rehabilitation actions will achieve the desired post-mining landscape and land capability aligned with end land use targets.
Stakeholder engagement & custodianship	• Relevant mining-affected stakeholders will be identified and involved in rehabilitation planning throughout the mining lifecycle, as required. • Rehabilitation planning will leverage from local stakeholder views, experiences, cultures and/or customs, on possible uses and needs of the rehabilitated landscape, to foster a land stewardship culture from potential next land users.
Landform	• Rehabilitation will be undertaken aligned to a site-specific surface landform design that will be compiled during the planning stage of an operation. • The site-specific landform design will incorporate the surface profiling needs of the target post-mining land capability and land use/s, to optimise material movement throughout the operational and decommissioning periods, and to ensure the long-term sustainability of the rehabilitated landscape. • A 'management-of-change review process' will be incorporated into the mine planning process, to ensure that changes to the mine plan do not compromise either the proposed final landform or its potential use

Component	Rehabilitation principle
Land capability	• Post-mining land capability will, as far as is practically possible, be constructed to resemble the pre-mining land capability of the disturbed area. • Attention will be given to rehabilitating the mine to specified land capabilities that can support a suite of mixed land uses. • Soil physical and chemical properties will be aligned to the productivity needs of the post-mining land use/s, and to support these in the long-term.
Land use	• Post-mining land use planning will consider the needs of changing regional development and planning, over time. • The site will be left in an environmentally physically safe, stable and non-polluting condition for the defined post-mining land uses. • The defined post-mining land use/s will provide socio-economic value to next land users, as agreed with these land users (once exact post-mining land uses can be defined).
Climate uncertainty	• Predictive modelling will form the basis for longer-term environmental impact identification and risk management.
Monitoring	• Monitoring will be initiated as soon as the first ground has been moved (at construction). • Monitoring will be continued progressively throughout the mining lifecycle, in parallel with concurrent rehabilitation activities. • Data obtained through ongoing monitoring will be frequently assessed for trends that could demonstrate rehabilitation success, and where corrective action may be required. • The monitoring process must be linked to a corrective action process.
Adaptive land management	• An adaptive land management approach will be adopted on-site, allowing for implementation of alternative and improved rehabilitation strategies and corrective action, where required.

4.2.3 Risk assessment

From a land rehabilitation perspective, an unwanted risk is one that has the potential to negatively impact on the delivery of site-specific rehabilitation objectives; it does not support the targeted post-mining land use and does not guarantee that this use will be sustainable.

Examples could include decant of poor-quality underground water; acidification of placed topsoil due to underlying acid-generating overburden/spoil material resulting in ultimate die-off of established vegetation; changes to surface topography as a result of settlement of backfill in open pits. Inappropriate use of previously mined areas may also result in water pollution, large-scale infestation by alien invader plant species, or even highly dangerous conditions such as spontaneous combustion.

The intention of a rehabilitation-related risk assessment is as follows (Figure 11):

- To identify events that could influence achievement of rehabilitation objectives and, ultimately, final closure and site relinquishment objectives (risk identification);
- To quantify the significance of the identified risks in terms of likelihood of occurrence and associated magnitude of impact (risk analysis);
- To evaluate the level of acceptability of occurrence and associated impact of the identified risks (risk evaluation);
- To devise appropriate mitigations or controls (rehabilitation actions) to prevent or reduce the impact of the identified risk (risk treatment), that should be implemented; and
- To compile a comprehensive risk register (list), that defines the key risks and their proposed controls, and allocates responsibilities for the management of each control.

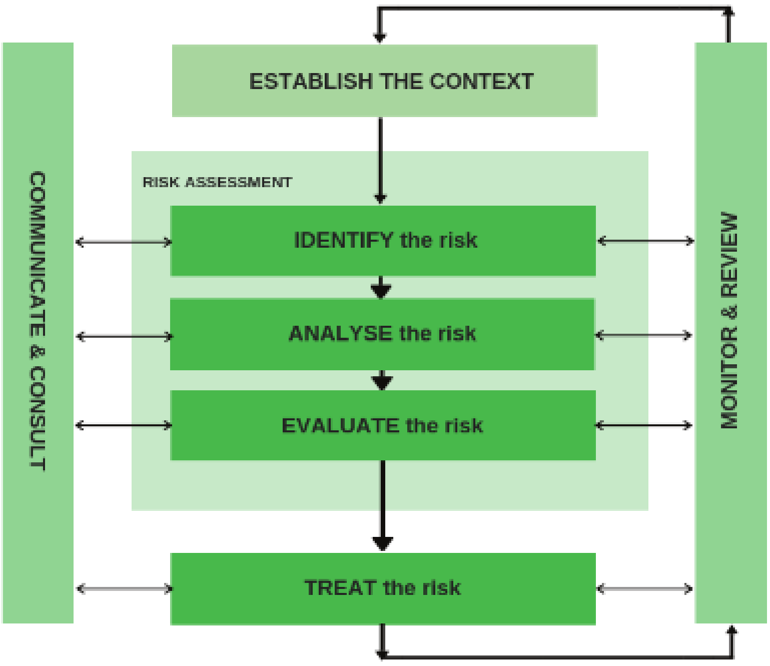


Figure 11: Risk assessment process for identification and management of rehabilitation risks

This process is aligned to the international Standard ISO 31000:2009 Risk Management Principles[24]. The risk assessment should be revised at regular intervals, or when an event occurs which changes the understanding of either the severity or probability of a key risk.

Analysis of rehabilitation-related risks can be undertaken at either a qualitative or quantitative level. A quantitative risk assessment uses theoretical or calculated data in the form of predictive models to determine the probability of the identified event occurring and the severity of its impact. This implies the need to refine specialist studies on specific rehabilitation-related aspects, aligned to changes in the landscape and/or based on results of ongoing monitoring and trend analysis. The rehabilitation knowledge base is, however, not usually extensive enough to perform a quantitative risk assessment. This is especially true for new or recently commissioned operations. In such cases a qualitative risk assessment can be undertaken.

A qualitative risk assessment does not analyse the risks mathematically, but rather uses expert judgment to rate the likelihood and consequence of an event in terms of descriptive words like “high”, “medium”, or “low”. As the site’s knowledge base improves over time, a qualitative risk assessment could be refined to a quantitative risk assessment to improve the accuracy of the allocated financial provision (for risk treatment). However, it is both pointless and misleading to attempt to do a quantitative risk assessment when insufficient relevant data are available for input, and when the models used are insufficiently tried, tested and verified as being fit for purpose.

The main benefit of qualitative risk assessment is that it helps prioritise which of the key risks to focus on.

Prioritising environmental risk assessment and mitigation as part of surface coal mining remains a critical step in successful sit rehabilitation


Photo: WF Truter 2018

[24] ISO 31000:2009 Risk Management Principles

4.2.4 Rehabilitation objectives

Well-conceptualised rehabilitation objectives will allow assessment of the risks associated with achieving these objectives and guide the setting of suitable rehabilitation actions to be taken to mitigate these risks at every stage of the mine's life. Rehabilitation objectives describe 'what' needs to be achieved to reach the mine's rehabilitation goal. These objectives should be aligned to site-specific characteristics that are within the mine's control.

Rehabilitation objectives should be as specific, measurable, achievable and realistic as possible. They should also define a time period against which they can be measured. The 'SMARTer' the rehabilitation objectives, the easier it is to clearly define relinquishment criteria against which rehabilitation success can be evaluated and approved by decision-makers (Table 3).

Table 3: Setting SMART rehabilitation objectives

SETTING 'SMART' REHABILITATION OBJECTIVES				
S	**M**	**A**	**R**	**T**
SPECIFIC	**MEASURABLE**	**ACHIEVABLE**	**REALISTIC**	**TIME-BOUND**
Concrete, detailed, well-defined	Concrete, detailed. Numbers, quantity, comparison	Feasible, actionable	Resource availability	Timeframes
Details exactly what needs to be done	*Achievement or progress can be measured*	*Attainable, within the resource and timeframe constraints*	*Attainable, within the resource and timeframe constraints*	*Time period for achievement clearly defined*

FOR EXAMPLE

Rehabilitation aspect	Example of a SMART rehabilitation objective
Surface landform design	To re-create a free-draining profile across the back-filled pits, having the correct gradient (slope between 1:14 & 1:7) for the planned land capability to support the intended land use - e.g grazing of livestock.
Land capability (soils)	To replace a soil cover of appropriate soils to a depth of between 250 – 600 mm (will be site-specific) on areas with suitable gradients (defined above) to achieve a grazing land capability over 80%* of the rehabilitated portions of the Mining Rights Area, in geographically delineated areas.
Vegetation cover	To maintain a productive and sustainable vegetation cover of appropriate pasture species (site-specific) that have a carrying capacity of between 1.7 and 5 ha/LSU and/or 5t/ha of hay, at a canopycover of ≥ 75%*.
Land use	Grazing land use over 80% of the rehabilitated portions of the Mining Rights Area classified with grazing land capability supports economic livestock production at the target pasture carrying capacities stated above.

Questions to ask when setting the rehabilitating objective

- What exactly is going to be done? / Is it clear what needs to happen?
- Is the objective well-understood by both those responsible for implementing it and those needing to sign it off?
- Is the objective described with verbs? (i.e. is it actionable?)
- Is it clear when it will happen?
- Is the outcome clear?
- Will the objective lead to the desired rehabilitation goal / outcome?
- Is it acceptable to Regulars, or decision-makers responsible for sign-off?
- Is it clear who is involved?
- Is the action based on achieving the identified point of site relinquishment? (Is it maintainable?)

*Variable, indicative values for explanatory purposes; not necessarily actual values – will be site-specific

4.2.5 Relinquishment criteria

The final milestone in a mining lifecycle arrives when decommissioning, final rehabilitation and post-operational care-and-maintenance activities are complete. It is the point at which the desired, authorised rehabilitation goals have been achieved. At this point, regulatory approval is sought for the relinquishment of the operational lease area on issuance of a closure certificate. For most mining companies, the desired outcome is to transfer responsibility for the lease area to a new landowner.

Relinquishment criteria can be defined as the measurable component of the final rehabilitation and closure objectives. They provide standards against which the success of the rehabilitation objectives can be measured[25], and enable the mine to determine when it should proceed with an application for closure[26] (Relinquishment criteria can also be referred to as success criteria, completion criteria, closure criteria, and/or release criteria).

FOR EXAMPLE

DEFINING RELINQUISHMENT CRITERIA		
Rehabilitation aspect	**Rehabilitation objective**	**Example of relinquishment criteria***
Surface landform design	To re-create a free-draining profile across the back-filled pits, having the correct gradient (slope between 1:14 & 1:7) for the planned land capability to support the intended land use - e.g grazing of livestock.	• Slopes of the rehabilitated areas delineated for grazing land are between 1:7 and 1:14. • Recreated drainage pathways areas 1:100 or flatter. • Surface topography directs runoff in a controlled manner towards defined rivers/streams within the local catchment, aligned with a site wide drainage plan; • Runoff velocities do not exceed predefined soil loss via erosion.
Land capability	To replace a soil cover of appropriate soils to a depth of between 250 – 600 mm (will be site-specific) on areas with suitable gradients (defined above) to achieve a grazing land capability over 80%* of the rehabilitated portions of the	• Replaced soil covers of the rehabilitated areas delineated as having grazing potential have been shown in post mining soil surveys to have**: – Soil depth ≥250 mm

[25] Brearley, D. (2003): Developing completion criteria for rehabilitation areas on arid and semi-arid mine sites in Western Australia. Curtin University of Technology.

[26] Australian Department of Industry, Innovation and Science (2017): Leading Practice Sustainable development program for the mining industry: mine closure.

DEFINING RELINQUISHMENT CRITERIA		
Rehabilitation aspect	**Rehabilitation objective**	**Example of relinquishment criteria***
	Mining Rights Area, in geographically delineated areas.	– pH between 5.5 – 8.5 – Pastures comprise at least three perennial specias suitable for grazing – Presence of a creeping (binding) grass on steeper slopes or where soils are erodible
Vegetation	To maintain a productive and sustainable vegetation cover of appropriate pasture species (site-specific) that have a carrying capacity of between 1.7 and 5 ha/LSU and/or 5t/ha of hay, at a canopy cover of ≥ 75%*.	
Land use	Grazing land use over 80% of the rehabilitated portions of the Mining Rights Area classified with grazing land capability supports economic livestock production at the target pasture carrying capacities stated above.	• Pasture yields from designated grazing land use areas support the intended livestock production rates.

* More relinquishment criteria addressed in Section C: Monitoring

**Variable, indicative value for explanatory purposes; not actual value

The mine needs to demonstrate that rehabilitation is either successful by proving that agreed-on relinquishment criteria have been met. Hence, monitoring of the relinquishment criteria must demonstrate the extent to which the rehabilitation objectives have been achieved. If monitoring confirms successful achievement of the relinquishment criteria, sign-off should be sought. On the other hand, if rehabilitation does not result in achievement of the rehabilitation objectives, the rehabilitation actions will need to be refined. If all modifications to actions have been tried, and the criteria still not attained, then the criteria should be reviewed – but this should only be done in full agreement with stakeholders.

Formal closure, sign-off and relinquishment mechanisms should be established with the DMR (lead regulatory agency). These should define responsibilities, accountabilities and proposed methodologies needed to achieve successful sign-off. This process re-emphasises the need to ensure that rehabilitation objectives and associated relinquishment criteria are drafted carefully to make them both measurable and achievable to allow for successful signoff and relinquishment.

While it is important to meet the requirements of the regulator, other stakeholders must be consulted in the development of site-specific criteria. Identifying relevant stakeholders and gaining their agreement on the site-specific relinquishment criteria is a critical step in mine rehabilitation planning.

4.3 Implement

4.3.1 Rehabilitation actions

Rehabilitation actions are the specific actions that describe *how* the rehabilitation objectives will be achieved, and *how* identified risks will be mitigated or managed.

Ideally, a rehabilitation action should be implemented *before* an impact occurs. These actions will not necessarily completely remove the likelihood of occurrence of the risk event, nor totally reduce the impact of the event. However, they need to reduce the rehabilitation-related risk rating to a level acceptable to decision-makers.

Rehabilitation should be undertaken concurrently as part of the mine's operations. Concurrent rehabilitation results in progressive, ongoing site rehabilitation to limit / manage future environmental, social and financial risks and associated liabilities. At the time of decommissioning, the only rehabilitation still to be completed should be that related to the small active spoil section immediately behind the final void, final void infilling, shaping and vegetating the final void and ramps, remaining portions of waste residue facilities and removal of surface infrastructure with no re-use potential and rehabilitation of all disturbed footprint areas. Post-rehabilitation, care-and-maintenance will involve actions required to maintain functionality of land, facilities and/or structures as part of the rehabilitated landscape.

Rehabilitation actions for surface mined land are provided in Section B of this Guideline.

Topsoil replacement on back-filled spoils

Coal ash dam rehabilitated to a grazing land capability

4.3.2 Roles and responsibilities

Putting a rehabilitation plan into practice needs actions in areas as diverse as finance, accounting, personnel management, procurement, production, environmental management, social responsibility, communications, and even sales. It is therefore far from being the sole responsibility of the operation's environmental team.

Effective rehabilitation planning (and development, management and implementation) requires a multi-disciplinary team to be established. The team should comprise at least the following key disciplines: environmental. social, water, financial, metallurgical and tailings, mining, mine planning, other relevant engineering disciplines, community relations and legal.

The multi-disciplinary team must also consider the dynamic nature of mining, such as changes in the mine plan and the introduction of new technological innovations, to define the potential impact of such changes on the eventual rehabilitation goals.

Each operation should designate one person to be responsible for coordinating rehabilitation planning and for overseeing the implementation of rehabilitation actions. This 'champion' would be tasked with keeping the mine rehabilitation up to date by identifying internal or external events that could have an impact on planning.

4.4 Monitor

4.4.1 Monitoring plan

Ongoing monitoring of rehabilitation activities against established rehabilitation action plans and relinquishment criteria enables tracking of the progress of ecosystem recovery over time. Monitoring enables early detection of rehabilitation 'non-successes' or unintended secondary impacts, and allowing for swift refinement of rehabilitation actions, or implementation of suitable interventions to correct the situation.


Photo: R. Hattingh 2017

A detailed, relevant and comprehensive monitoring plan must be developed to confirm that the rehabilitation actions and relinquishment criteria, as defined in the rehabilitation plan, are being met. The monitoring plan must be implemented as soon as work begins on the mine to start collecting the information required to confirm the effectiveness of the rehabilitation actions, and to refine the rehabilitation plan, as necessary.

A detailed annual monitoring programme should be drawn up, consisting of the following sections:

- Reason for monitoring and monitoring objectives (economic, agronomic, ecological);
- Explanation of recognised or acceptable monitoring methodologies and standards used;
- Spatial extent and timeframe for monitoring (areas, time post-rehabilitation, heterogeneity of sampling method, number of representative monitoring points, frequency of monitoring activities);
- Monitoring criteria outputs (e.g. soil nutrient status, soil microbial activity, vegetation cover, plant root development, vegetation species richness/composition, infiltration rates, dry bulk density, etc.) and methods employed to assess these;

- Monitoring schedule - which monitoring actions are undertaken during which months and at what post-rehabilitation stage?
- Monitoring resource requirements - inclusion of specialists, manpower allocations, specialised equipment, laboratory requirements and protocols; and
- Information feedback - the information generated by monitoring activities must have a defined feedback into improving site conditions by translating poor performance or gaps directly into specifications to rectify these.

The monitoring should consider the wider receiving environments, receptors and exposure pathways.

There have been significant advances in monitoring technology in recent years, particularly utilising aerial imagery and hyperspectral remote sensing to detect landform design deviations, highlighting subsidence/cracks and even vegetation cover, sward vigour, woody plant density and crop nitrogen content.

All monitoring should be focussed towards final site closure by compiling a defensible record of performance over time, that meets post-mining land use objectives and adequately mitigates current, latent and residual environmental risks

More detail on the monitoring plan is provided in Section C: Monitoring.

4.4.2 Data management

Having the right information to make the best technical, environmental and social decisions in rehabilitation planning requires the collection, assessment and management of environmental, social and economic data[27]. A dedicated record of data, as captured in the site's environmental management system (EMS), should be used to generate information and hence knowledge needed to refine of the site's rehabilitation plan (Figure 12).

Collection, measurement and analysis of data to support rehabilitation decisions

[27] Australian Department of Industry, Tourism and Resources. (2011). A Guide to Leading Sustainable Development in Mining.

USING DATA TO GENERATE INFORMATION, THAT RESULTS IN KNOWLEDGE

TERM	CONCEPT	EXAMPLE
Using DATA	• Captured symbols and readings (recorded and stored) • Objective facts (numbers, symbols, figures), with no context or interpretation • Description of events	• Raw monitoring results • Results of questionnaires, polls • Records of stakeholder complaints and suggestions
To generate INFORMATION	• Message that contains a relevant meaning for a decision or action • Data in context • Meaning or sense of data arising from ists interpretation	• Water quality in a particular location, or over a specific time frame • Changes in rehabilitated land capabilities • Causes of stakeholder complaints
That results in KNOWLEDGE	• Cognition (what-to-do) • Ability to act (know-how) • Understanding (know-why, know-where)	• Appropriately managing site decant • Providing specifications for long-term land management • Developing projects to improve community livelihoods

Figure 12: Use of data to generate information that can inform a mine's rehabilitation-related knowledge base

Early identification of data and information gaps helps guide what is needed in the way of additional monitoring requirements, and additional research/investigations. The information acquired will allow the mine to assess the effectiveness and success of their currently unproven rehabilitation strategies. A data recording and management system will help the planning team to:

- Develop and maintain a consolidated, centralised rehabilitation and closure knowledge base, accessible by the entire mine (and corporate) team, that includes at least the following:
  - Soil stripping guides – soil types and locations, materials balance for operations vs rehabilitation, stripping ratios, distance stripped ahead of mining, etc.;
  - Soil stripped vs soil stripping plan volumes;
  - Planned vs completed surface profiled areas;
  - Surface profiled areas available for sign-off as having met design criteria;
  - Soil stockpiles – locations, volumes, planned replacement volumes and locations;
  - Soil amelioration plan – physical, chemical and biological. Both at soil replacement and ongoing needs;
  - Revegetation plans – species, application approach, fertiliser programmes, etc.
- Use data and information to analyse performance trends, over time, towards being able to determine the rehabilitation success trajectory; and
- Retain corporate memory to ensure good learnings are shared for implementation and to avoid repetition of mistakes.

It is necessary to continually review new information gathered throughout the life-of-mine. As a site's rehabilitation planning is reviewed, updated and refined on an annual basis, new data and information should be captured and integrated into a central data repository.

4.5 Refine, correct, re-plan

The main benefit of the monitoring should be to ensure that rehabilitation actions are actually implemented! In most cases, although the planned actions are adequate for the associated impact, the implementation is either late or incompletely done, leading to failure to achieve the objectives. Too often, a good plan is 'refined' because the mine has not allocated the correct resources or mapower to implement the actions correctly and fully.

When ongoing monitoring outcomes support the need for refinement, these new or corrective actions should be captured in the mine's EMS, and implemented. The actions should have an assigned responsible person, with adequate funding made available to implement and close out the action.

Aligned to the South African legislative requirements (NEMA Financial Provisioning Regulations), a mine's rehabilitation reporting will be reviewed and updated on an annual basis going forward. This includes annual assessment of the rehabilitation plan, the closure plan and the rehabilitation-related risk reporting. This provides an ideal opportunity for an operation to keep its rehabilitation records up-to-date and, if necessary, to refine and/or re-plan in a proactive manner.

Once the rehabilitation success trajectory has been verified through monitoring data trend analysis, the final risk assessment can be undertaken, post-closure monitoring can be defined, and mechanisms can be put in place to remediate and/or managed any new risks that may emerge.

This refine-correct-re-plan approach ensures that the site's rehabilitation planning is continuously being adapted and improved, aligned to new site information, as required. It remains an iterative process until final site relinquishment has been obtained.

ADDITIONAL RESOURCE

Rehabilitation Requirements for Mining Resource Activities
(Australian Department of Environment & Heritage Protection, 2014 - Queensland)

SECTION B: IMPLEMENTATION

Good upfront preparation and development of a well-structured rehabilitation plan is only part of effective mine site rehabilitation planning. Focussed, well-managed on-site implementation of the identified rehabilitation actions is a critical step in achieving a successful rehabilitation outcome.

This section of the Guideline builds on years of practical experience. It provides practical advice for rehabilitation practitioners to ensure that properly rehabilitated surface coal mined land has ecosystem functionality and that post-mining land use is both sustainable and economically viable.

Guidance is provided for the following core components of land rehabilitation (Figure 13), indicating their implementation sequencing from the bottom-up:

- Surface landform design and profiling (Section 5);
- Soil stripping, stockpiling and replacement (Section 6, Section 7, Section 8);
- Soil amelioration (Section 9);
- Revegetation (Section 10); and
- Surface infrastructure (Section 11).

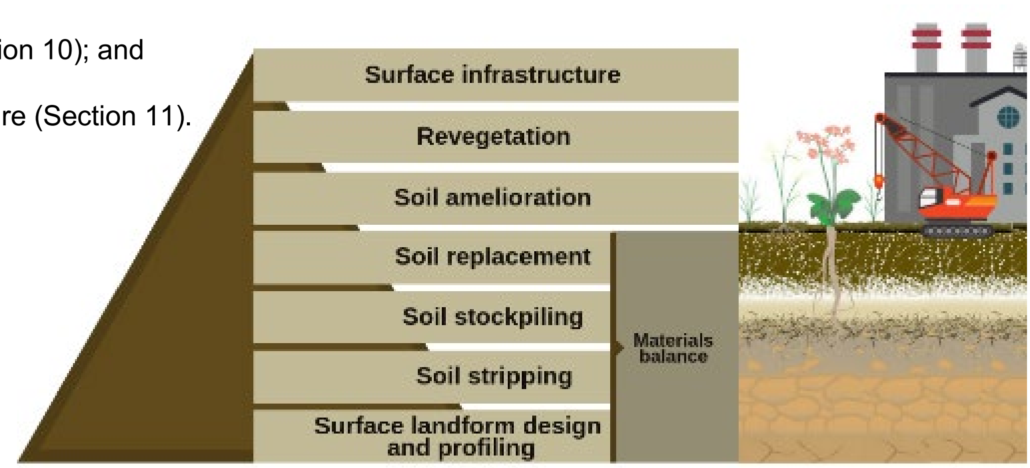


Figure 13: Layout of the systematic approach to the land rehabilitation actions provided in this Guideline

For each core component a rehabilitation context, generic rehabilitation objectives and associated implementation actions are provided. Possible monitoring criteria as well as parameters for setting associated relinquishment criteria are also provided, together with some examples (in brackets). As site knowledge improves, rehabilitation objectives, actions, and monitoring criteria will need to be refined with specific and measurable parameters that can be signed-off by the decision-making Authorities.

NOTE: **Every site has its own climatic, biophysical and social conditions. The guidance provided will need to be tailored for each operation, aligned to the outcomes of site-specific studies and monitoring data.**

To set the rehabilitation context, Figure 14 illustrates the key challenges faced by surface coal mines when undertaking standard rehabilitation practices. This compared to the potential long-term ecosystem-wide opportunities delivered by sites implementing good rehabilitation practices.

These challenges and opportunities focus on the core biophysical aspects of land rehabilitation to be discussed in the following sections.

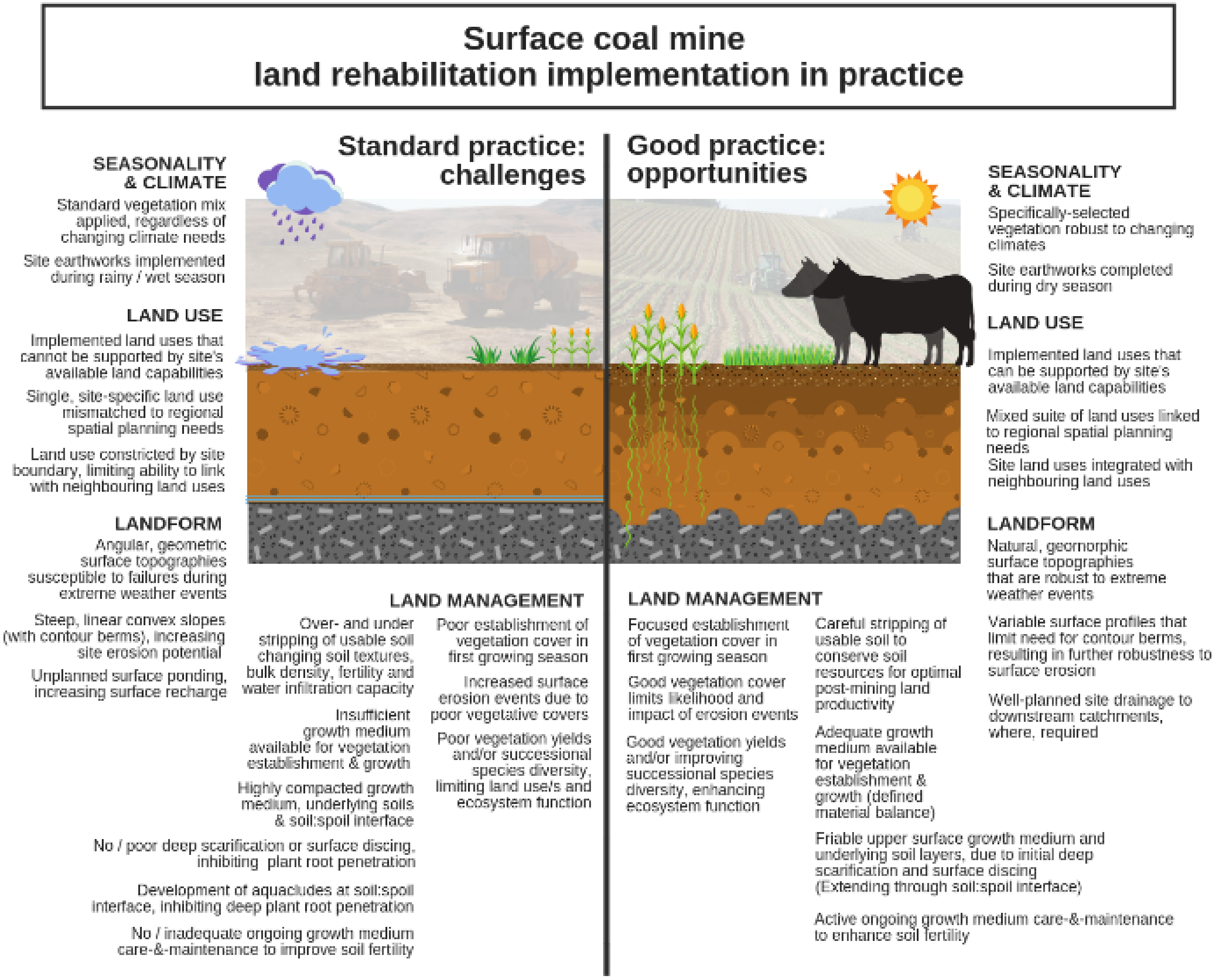


Figure 14: Land rehabilitation on surface coal mines – implementation challenges and opportunities

5. SURFACE LANDFORM DESIGN AND PROFILING

5.1 Context

Landform re-creation (spoils shaping) is the process by which the mined overburden materials are placed and moved to create the desired final topography. Cost considerations frequently prevent the full replacement of all mined-out materials back into the original excavation and, in many open-pit operations, the resulting topography consists of an overburden dump and a void.

There remains considerable scope for the reshaping of both void and overburden to provide a final landform that will have improved post-closure usefulness. The key is early planning of the post-mining landform to ensure that overburden materials are placed in the most appropriate location.

While the current norm is to ensure that the final landform is free-draining and has slopes that minimise erosion risk, the desired approach is to ensure that the final landform conforms as closely as possible to the agreed final configuration and blends in well with the surrounding landscape. This is frequently difficult to achieve, as unpredicted variations in the mineral body frequently dictate changes to the mining plan, with often significant effects on the planned landform. Changes to mining plans should be strictly controlled, and before such changes are implemented their impact on the final landform needs to be fully appreciated, and the required mitigation measures put in place to ensure that the overall rehabilitation objectives are still being met.

One of the key uncertainties in final landform prediction is the bulking factor. Soft materials frequently compact by as much as 15%, while hard materials may expand by as much as 30%. As a consequence of these factors, it is difficult to predict the final landform accurately and the standard commitment to landform re-creation should relate to agreed outcomes, such as the maximum slopes to be permitted over specific areas, and a commitment to maximise free surface water drainage.

Surface re-shaping in progress

Re-shaped surface profile

5.2 Rehabilitation objectives

The following rehabilitation objectives should guide surface landform design and profiling:

Objective 1	To integrate concurrent rehabilitation designs into life-of-mine plans, encouraging direct soil placement as part of rehabilitation activities, where possible.
Objective 2	To optimise the way material is moved during operations, to ensure that overburden and topsoil stockpiles, and/or other usable materials are placed in suitable locations to minimise rehandling and to minimum haul distances for rehabilitation and/or closure activities.
Objective 3	To create a planned rehabilitated landscape that meets predefined land capabilities commitments, and which has: • Suitable slope profiles for the planned land use/s and that limit the potential for erosion; and • Adequate soil cover thickness.
Objective 4	To recreate a landform that is aligned with the long-term water management requirements, and that: • Limits ingress of water through backfilled open cast spoils that could require ongoing water management in the long-term; and/or • Ensures adequate water availability for post-mining land use/s
Objective 5	To ensure that sufficient soil (growth medium) is kept in stockpiles to backfill any areas of settlement (melon holes) so as to keep rehabilitated areas free-draining and to conserve land capability.
Objective 6	To limit the need for, or intensity of, long-term care-and-maintenance of recreated landforms.

5.3 Actions

The following actions should be implemented to guide the development and implementation of a suitable surface landform design:

Action 1	• Develop a post-mining surface landform design at the planning stage.
Action 2	• Include landform designs for the rehabilitated boxcut spoils, final voids and overburden dumps if these remain at closure.
Action 3	• Comply with land capability commitments.
Action 4	• Reduce slope length on large overburden mounds or in rehabilitated areas with excessive slope length by increasing drainage density.
Action 5	• Manage the effects of surface settlement on the re-profiled landscape.

Action 6	• Monitor spoil reshaping to ensure conformance to the requirements of the modelled landform design.
Action 7	• Assess the effects of changes to mine plan on final landform.

5.3.1 Develop a post-mining surface landform design at the planning stage

The greatest amount of surface disturbance, and hence the greatest need for mining residue reshaping, usually occurs when mining is done by strip-mining, open-pit or block caving methods. Long-wall mining usually has a lesser impact, but in shallow coal situations it can have severe disturbance effects at surface and will invariably affect surface water flow and impact land capability.

The mining method used is normally dictated by the nature of mineral reserve and is usually fixed during the project stages of mine planning. However, with mineral reserves that are relatively shallow, truck-and-shovel strip mining methods can produce a far superior final landform as there is more flexibility in the placement of backfill than with dragline operations.

Whatever the options are, the conceptual framework for the final topography will have been set during the planning/permitting phase and this will be the end-target to which the mine will have to work. The final topography will be a function of original topography, mining method and reshaping strategy.

In the planning phase, the landform design must take account of:

- Volumes of ore or product removed from the pit;
- Expected bulking factors for the remaining overburden/interburden materials;
- Long-term material settlement factors;
- Predefined post-mining land use, and associated land capability criteria of the rehabilitated landscape;
- Long-term water management requirements of the post-mining land use/s; and
- The need to keep water out of the mined area during the operational phase but ensuring that adequate water flow is in place for the rehabilitated landscape (if required to maintain the post-mining land functionality).

The diversion systems designed to keep surface water out of the pit for operational requirements may not be suitable for the post-mining phase. Where required, though, operational diversions should be designed to remain effective post-closure.

The post-mining landform commitments should relate to broad concepts such as free drainage and provision of areas with certain slope characteristics (land capability requirements) rather than to the provision of a geo-referenced detailed final design that may be economically impossible to achieve.

Modelling has, however, proved to be of significant value when used to determine how to modify existing rehabilitated topography to attain final closure objectives in the most cost-effective way.

The landform design is refined from concept, to preliminary (initial), to detailed (final) design, for on-site implementation. Although the concept and preliminary designs may need to be refined as the mine plan changes, implementation of the landform design as soon as mining begins is imperative. This will ensure that there is no delay in concurrent rehabilitation activities, with the mine in full control of direct placement of stripped soils as rehabilitation progresses.

APPENDIX

Appendix C:
Considerations for final landform, modelling, drainage and sustainability

5.3.2 Design for boxcut spoils, final voids and overburden dumps

For some opencast or strip mines, it has not been, and may not be, possible to replace overburden materials into the mined-out space. The result, in the case of strip mining, is the creation of boxcut spoils (the piles of overburden created when the first mining cut is made) and a final void (the final mining cut).

Some mine plans require that the boxcut spoils be used to fill the final void - this is usually to improve water management across the rehabilitated landscape but may also be to maximise post-mining land capability. Backfilling the final void is always costly, which highlights the need for the mine planning to account for boxcut spoils being trucked to a stockpile located adjacent to the position of the final void when mining starts (to reduce costs at closure). Alternatively, the mine may get an EMP approved that agrees to rehabilitating the boxcut spoils *in situ* and accepting a final void/pit lake at closure, requiring no backfilling.

With boxcuts, voids and dumps, basic requirements and principles for topographical reshaping remain the same:

- To minimise slope lengths that will result in optimised planned land capability; and
- To minimise erosion risk.

Geomorphically designed flatter outgoing slopes

Re-shaped final void

Slopes required to minimise erosion risk can be calculated from slope length, surface soil characteristics, profile drainage and rainfall intensity. Slope lengths of rehabilitated landscapes are often too long, resulting in structural physical instability and excessive erosion. Resistance to erosion can be enhanced by modifying slope design to mimic natural slopes (referred to as a 'geomorphic approach'). The slope inclination can be steeper (even convex) at the top of the slope (where water accumulation is less) but should be flatter (and concave) towards the foot of the slope (where water accumulation is more). (In some cases, concave slopes present three times less erosion than linear slopes[28]).

The ability to pre-design more natural slopes, of appropriate length, can contribute to the landform's natural robustness. This is by reducing the velocity of accumulated runoff water over the placed cover soils, minimising the likelihood of significant erosion. It can also avoid the need to design and install contour berms on rehabilitated land where they have been proven to be ineffective in the long-term. Where berms are used extensively as part of the rehabilitation design, significant ongoing care-and-maintenance is required. Cattle tend to walk in single lines across berms, generating erosion pathways that result in overtopping or slope failure. These areas need to be continually re-shaped and in-filled. Maintenance of berm vegetation also proves to be a challenge, exacerbating erosion in these areas.

The design should also allow for modelled landform evolution processes over time, demonstrating how the movement of placed cover soils downslope (as a result of erosion) may result in shallower soil depths than required for the maintenance of the predefined land capability.

There is another important factor to consider in determining the final landform design. This is the post-closure water balance and the potential to use pit lakes to provide sufficient evaporative surface to match the pit water "make". This approach is only possible where annual evaporation exceeds rainfall. In this

[28] Priyashantha, S., Ayres, B., O'Kane, M., and Fawcett, M. (2009): Assessment of concave and linear hillslopes for post-mining landscapes. 8th ICARD Conference – Sweden.

way, seepage of polluted water out of the pit can be minimised. Evaporative water use may not be approved by the authorities in water scarce areas.

Well-designed geomorphic landforms *can* be resilient against erosion over time, and provide stable, natural drainage lines that require limited/less long-term maintenance due to their natural robustness.

5.3.3 Comply with land capability commitments

The post-mining land capability requirements as defined in the site's EMP are critical aspects against which to design suitable rehabilitated slopes. Sustainability of the re-instated land capabilities, adequacy of soil cover thickness and limiting erosion of the placed cover are imperative in ensuring this long-term design compatibility.

Land capability classification depends on several factors – the most important of which relate to topography and soil erodibility. For the higher capability classes (arable and grazing), slopes need to be sufficiently gentle to prevent erosion of the replaced soils, with slope angle being determined as a function of soil erodibility. The erodibility of soils depends on several factors, such as regional rainfall intensity, soil type, soil texture and soil organic matter content, so that a standard slope cannot be recommended for the whole country.

However, for rehabilitated areas in the Mpumalanga Highveld, standards have been set by various companies, who use a slope of not more than 1:5 or 1:7 for grazing land and not more than 1:10 or 1:14 for arable land. (Determining the appropriate slope angle for any given soil, so as to minimise erosion, is discussed more completely in Appendix D).

Land re-shaped to arable land capability requirements

Land re-shaped to support pan functionality

Excessively steep slopes can reduce land capability despite adequate soil depth and soil quality. However, there is also a minimum slope that is acceptable. This is because, with currently used overburden handling techniques, materials that are dumped and levelled undergo secondary, differential settlement. This can result in an undulating topography with frequent melon holes in an otherwise relatively level rehabilitated land.

While this may not be an issue where rainfall is relatively low and drainage through both soil and overburden is good, impeded drainage in higher rainfall areas may result in the creation of many “swampy hollows”, which significantly reduce the land’s usefulness for mechanised field crop production and will result in the downgrading of capability classification from arable to grazing, or even to wilderness. It is easier to create free drainage, even where secondary subsidence occurs, if the general slope of the land is steeper than 1:100.

APPENDIX

Appendix D:
Determining the soil erodibility factor (K)
(MinCoSA, 2007)

APPENDIX

Appendix E:
Definitions of land capability classes
(AGIS, 2011)

5.3.4 Reduce slope length on large overburden mounds or in rehabilitated areas with excessive slope length by increasing drainage density

The ideal is to avoid the construction of drainage channels on rehabilitated ground. This may be possible where:

- Slopes are short; and
- Stabilising vegetation cover grows with the first rains.

However, this is frequently not the case and erosion control structures have to be installed in the rehabilitated landscape to control runoff and minimise erosion.

There are a number of surface water drainage systems that are in common use and the design requirements to deal with particular climatic conditions, and soil and slope characteristics, are well known for unmined land.

The difficulty lies in the practical application of these designs to rehabilitated land. Many well-designed (by normal standards) surface water drainage systems have made erosion worse on rehabilitated land.

The key problem is the differential settlement that occurs as mine spoils consolidate. Settlement can take many years to complete and is usually greatest in the first few years after rehabilitation, but another “spurt” of settlement occurs after mining stops and as the rebounding water table wets the overburden materials resulting in further settlement.

To counter this, gradients used within the drainage “contour banks” must be significantly steeper than their equivalents on unmined land and the batters must be higher. Whereas gradients of 1:200 are frequently used for contour drains on unmined ground, on gradient of contour drains on rehabilitated land should not be less than 1:100. In many cases, gradients of 1:60 are strongly recommended. These steeper slopes may result in some scouring within the channel itself, but the risk of the contour banks or drains breaking is greatly reduced.

APPENDIX

Appendix F:
Considerations for surface drainage structure design
(MinCoSA, 2007)

5.3.5 Management of the effects of differential settlement on re-profiled landscapes

In coal mining, it is standard practice to backfill the newly mined-out voids with the excavated waste rock and sub-soils. The backfilling is generally done with draglines that side cast the spoil material in windrows or using dump trucks to place the spoil material back into the pit.

The thickness of the end-dumped mine spoil can vary from a few metres to tens of metres deep. Dragline casting of the spoil creates a fairly loose mass that has a tendency to settle, reducing the void space between particles over long periods of time. This reduction in void space causes the spoil to ‘differentially settle’, resulting in depressed patches that can result in waterlogged of the overlying soils. For dragline-dumped mine spoil, settlement is more pronounced than for spoil backfilled using truck-and-shovel operations, as there is limited compaction inside casted spoils.

Factors affecting the magnitude of settlement, and the duration over which differential settlements occurs, include placement procedures, material composition, depth of fill, age of fill, groundwater levels, rate of surface water infiltration and loading conditions.

The effect of differential subsidence is to downgrade the standard of rehabilitation in two ways:

- Localised hollows (melon holes) may become wet spots which present management problems irrespective of whether the land is destined for grazing or arable use; and

- Subsidence on sloping topography will cause failure of anti-erosion structures, such as banks and furrows, that have been constructed according to immediate post-levelling contours. This will lead to rill and gully erosion at points of failure.

In practice, differential subsidence is unavoidable.

One method of remediation is to retain a stockpile of soil material to fill in the depressions, thus ensuring that satisfactory surface drainage will be maintained. (This is addressed in Section 8: Soil replacement).

Groundwater make will increase due to enhanced ingress of ponded water through the backfilled spoils. In-filling of settled areas with stockpiled soils (specifically designated for care-and-maintenance purposes) will reduce surface depressions. Planting of trees or water-intensive vegetation to increase evapotranspiration is also an option.

Access to areas showing signs of settlement should be restricted by installing appropriate warning signs and/or fencing, until the areas have been re-filled and shaped.

Settlement around a monitoring borehole on dragline-placed spoils

A settlement monitoring programme should be established to determine, and assess, high-risk areas. This should include:

- Identification of high-risk areas for settlement (as defined in the site's environmental risk assessment);
- Trigger levels for subsidence impacts that require actions and responses;
- Procedures that would be followed in the event that the monitoring indicates an exceedance of trigger levels;
- Protocols for the notification of identified trigger level exceedances at any monitoring points;
- Measures to mitigate and rehabilitate any identified impacts.

5.3.6 Manage sub-surface drainage (groundwater flow)

Saturated flow of water through soil varies with porosity and, inversely, with bulk density. An increase in bulk density not only reduces total porosity, but usually also shifts the pore size distribution in the direction of a smaller average pore size. As flow rate of water through soil decreases as the fourth power of pore radius (e.g. halving pore size decreases flow rate by a factor of 16), compaction at the soil-spoil interface or at any other shallow depth can have a profound effect on plant growth and land use.

When a compacted layer occurs near the surface and underlies a more permeable layer, the less permeable layer limits the rate of flow of water through the profile. This results in water starting to accumulate at the contact between the two layers. This water may move laterally by sub-surface flow to daylight in topographic lows resulting in unwanted wet or marshy spots. Conversely, on relatively level topography, where lateral flow is slow, a seasonally fluctuating, perched water table may develop. This will provide a barrier to root development through waterlogging, reducing even further the effective depth of soil. The perched water table may even reach the surface and discharge by overland flow, developing potential further erosion risks.

Daylighting of sub-surface water due to underlying compacted layer hindering water movement through the replaced cover profile

5.3.7 Monitor spoil reshaping

Regular reconciliation of overburden volumes moved in relation to the mining work programme should be done. Where possible, survey results should be used to correct bulking factors employed in the original planning exercise, so that conceptual planning can be improved. It is most important to ensure that spoil deposition is done according to plan and that spoil reshaping is also done to specification. While the frequency of review or monitoring of post-deposition topography may justifiably vary from site to site, it must be frequent enough to ensure that any major deviations from the planned post-mining topography are identified soon enough to enable them to be corrected. Depending on the rate of pit development, formal review should be done on a monthly, quarterly or annual basis.

5.3.8 Assess the effects of changes to mine plan on final landform

All changes in the mining plan should be analysed for their effects on final landform design. Significant modifications to the mine plan and final landform will require modification to the mine's EMP, which would need to be resubmitted to government for approval.

5.4 Monitoring criteria and relinquishment parameters

The following monitoring criteria could be used to define achievement of rehabilitation success. Parameters for setting associated relinquishment criteria are also provided.

		Relinquishment parameters
Monitoring Criterion1	• Alignment of actual spoils and overburden placement compared to designed material movement and placement plan.	• Location and placement of spoils and overburden is aligned to the agreed-on site-specific landform design (*map and design criteria*).
Monitoring Criterion 2	• Alignment of actual reprofiled surface topography (slope profiles) compared to designed topography.	• Slope angles (profiles) are aligned to the agreed-on site-specific *landform design*.
Monitoring Criterion 3	• Actual areas (hectares) rehabilitated to different land capabilities compared to planned areas.	• Achievement of predefined area (*ha or % of rehabilitated area*) per land capability class implemented. • Rehabilitated areas functioning in terms of predefined land capability classes (independent *land capability assessment*).
Monitoring Criterion 4	• Stability and effectiveness of water management infrastructure under a range of rainfall events, over time.	• Water management infrastructure operating according to design specifications, under a range of rainfall conditions, and over time (*landform design*).
Monitoring Criterion 5	• Actual rate and effect of surface subsidence compared to predicted (modelled) rates.	• Area (*ha*) and rate (*cm/annum*) of settlement does not affect: – Implementation of predefined land capabilities; or – Ability of land user/s to implement predefined land use practices (e.g. use of farming equipment; access to land by livestock, etc.)
Monitoring Criterion 6	• Actual care-and-maintenance applied compared to planned requirements.	• Record of care-and-maintenance of landforms and water management infrastructure is within predefined quantities (*ha*). • Post-Mining Land Management Plan in place, indicating ongoing management and care-and-maintenance requirements of recreated landforms and water management infrastructure.

6. SOIL STRIPPING

6.1 Context

Soil, once lost, it takes many years to regenerate.

The availability of soil materials is the key to successful rehabilitation. The surface layer that contains the fertility and seedbank should be stripped and stored separately.

Soil stripping should remove all usable materials that are suitable for supporting plant growth. This is typically the A and B1-horizon soil. For example, heavy clays can be used to seal drainage lines and planned depressions, while sands may be used to provide breaker layers in discard facility covers. *Usable soils* typically comprise well-drained soils suitable for rehabilitation, and also contains the natural seed bank that can improve vegetation biodiversity if the soil is live placed. In practice, the thickness of usable soil varies considerably. It is normally less than 1m thick, but on occasions may be as much as 3 - 5 m thick. The pre-mining soil survey will identify those horizons (normally down to a depth of 1.2 m - limited by the length of the hand-held soil auger used) that will support plant growth, and those that will be less effective.

Experience has shown that significant losses of soil materials occur during the stripping and replacement processes, and it is advisable to strip and retain the deep materials when these have been identified. Planning the removal and stockpiling of soils will increase effectiveness of the rehabilitated end product.

6.2 Rehabilitation objectives

The following rehabilitation objectives should guide soil stripping:

Objective 1	To develop a comprehensive understanding of the site's soils to be able to compile an appropriate soil stripping and handling plan for the entire lifecycle of the mine.
Objective 1	To strip demarcated usable soils according to a soil stripping and handling plan.
Objective 3	To live place as much of the stripped soil as possible, to minimise the quantity of usable soil needing to be stockpiled.
Objective 4	To undertake soil stripping in a manner that limits soil loss and compaction and retains as much of the natural seed bank as possible.

6.3 Actions

The following actions should be implemented to guide appropriate soils stripping:

Action 1	• Ensure that there is a detailed soil survey for the areas to be stripped.
Action 2	• Generate a soil stripping and handling plan.
Action 3	• Always strip a suitable distance ahead of mining to avoid soil loss and contamination from throw/blast rock.
Action 4	• Demarcate boundaries of different soil types.
Action 5	• Define usable soil cut-off horizons in simple terms that the stripping operator can understand.
Action 6	• Supervise stripping to ensure different soils are not mixed.
Action 7	• Strip soils only when moisture content will minimise compaction risk (soils must be below their plastic limit when handled).
Action 8	• Strip and replace soils in one process wherever possible.
Action 9	• Use a shovel and truck fleet in preference to bowl scrapers.

6.3.1 Ensure that there is a detailed soil survey for the areas to be stripped

A detailed soil survey must be generated before mining or construction begins towards being able to define a site-specific materials balance for rehabilitation. The soil survey will have been done as part of the mine EIA/EMP studies. This will contain the basic data concerning the soils types, soil texture and soil depths.




Surface profiling | **Soil stripping** | **Soil stockpiling** | **Soil replacement**

Materials balance

While a pedologist will produce a soil survey that defines the physical and chemical limitations of the soil, there is also a need to include a biologist in the process of defining the soil horizons to be stripped for rehabilitation. This is because the soil, in addition to providing the chemical and physical requirements to support plant growth, may also be the principal or sole source of seed of native plant species required for rehabilitation. It may also be the case that the area is heavily infested with alien vegetation. Soils taken from weed infested areas for use in rehabilitation will need to be more carefully monitored and managed as they will probably require more intensive weed control in at least the first few years.

All soil material suitable for supporting plant growth in the rehabilitation phase should be stripped and replaced on reprofiled spoils, or carefully stored for re-use.

6.3.2 Generate a soil stripping and handling plan

The soil physical, chemical and biological data collected during the soil survey should be combined to generate a detailed soil stripping and handling plan.

Gleyed soil mixed with "good" soil

Wherever possible, soils should be stripped and immediately replaced in a similar location in the catena (topographical slope) to their natural location. Accordingly, red soils are best located on the crests, yellow-brown soils on the mid-slopes, sandy leached soils near the base of the slopes, and melanic and vertic (dark and black cracking) soils in the low lying wet areas at the base of the slopes. The plan should define the total volume of the different soil materials that will be available for rehabilitation, and should also define the thicknesses to which the soil should be replaced in designated areas on the reshaped spoil surface

Soils should be stripped by horizon. The ideal situation would be to strip soils in at least three 'lifts':

- Firstly, the surface soil, which contains the seed bank, would be removed. Typically, this would be 50 - 200 mm thick.
- Secondly, the rest of the A-horizon – that portion of the surface soil that contains the bulk of plant roots and humified organic matter, would be removed. Depending on the age, erosion exposure and rainfall regime, the A-horizon thickness in total may be 400 – 600mm in thickness.
- Thirdly, the usable non-plinthic B-horizon materials (usually B1-horizon) would be removed. These materials are physically suitable for rehabilitation but contain little or no organic matter and fertility and, accordingly, will not sustainably supply planted crops or grasses with nutrients if used as topsoil.

Three-layer stripping and replacement is not currently practiced by the mining industry in South Africa, largely because it is impractical when using large earthmoving equipment. The damage that can be done to the underlying soils when stripping individual horizons (mainly through compaction from wheel tracks) also makes this approach inadvisable.

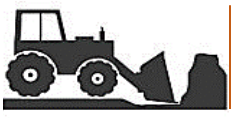
In most cases, standard South African practice is to strip the A-horizon and non-plinthic B- horizon together, and then to replace them together. This significantly dilutes the more fertile surface materials and increases requirement for fertilisation and seeding. It is, however, the simplest to manage from an earthmoving point of view.

However, some operations strip and replace soil in two layers: the organic enriched A-horizon, which is usually 250 - 400 mm thick, is stripped and replaced separately from the usable B-horizon material. In this case, the seed bank is spread throughout the replaced topsoil horizon and natural vegetation regeneration is slower than would be the case in the 'ideal' situation. This emphasises the importance of appropriate soil amelioration (fertilizer application) to enhance vegetation establishment and growth.

Unfortunately, suitable placement areas are often not available when soils of a particular type are being stripped. For example, if wetland soils are being stripped, they cannot be placed directly on available midslope areas that require well-drained soils, and vice versa. This is when topsoil stockpiling becomes necessary. Guidance for soil stockpiling is given in the next section.

Good practice would require the soil stripping and handling plan to show:

1. A georeferenced survey defining soil types, with horizons and depths to be stripped.
2. Areas to be stripped, and when stripping should be done. It should also show the volumes of the different types of soil that will be available for rehabilitation at the various stages of the mine's development. This plan should be updated at least on a 6-monthly basis.
3. Where the various stripped soil horizons are to be placed. The preference is always for direct placement, but where this is not possible due to insufficient surface area having been reshaped to the final profile, a significant volume of soil will have to be stockpiled. The soil volumes will also need to be updated on a 6-monthly basis.
4. The proposed final distribution of replaced soils, both in terms of types of soil material used and of thickness applied.
5. A soil materials balance, with volumes to be moved at various times throughout the life of mine, so that appropriate planning of manpower and machinery resources can be done.



APPENDIX

Appendix G:
Example of a pre-mining soil survey, and soil stripping and use plan
(MinCoSA, 2007)

6.3.3 Always strip a suitable distance ahead of mining to avoid soil loss and contamination

It is sometimes difficult to define what is meant by "a suitable distance" ahead of mining. There are two conflicting environmental imperatives at work here:

The first is to ensure that the area stripped ahead of mining is not too large. This would expose the stripped surface to the risk of water and wind erosion, with the associated dust and water sediment pollution problems. The second is that if the stripping face is too close to the mining face it frequently results in the loss of valuable soil material. The loss is primarily due to contamination by fly-rock from blasting operations in the adjacent active mining cut. The fly rock can originate from blasting of the overburden or from blasting of the coal seam. In the latter case the fly rock is typically carbonaceous, with added contamination potential. However, it is preferable to strip a little too much ahead of mining rather than too little, particularly where stripping is concentrated in the dry months to minimise the potential for compaction. As a norm, soil stripping should be kept within 3 - 9 months of mining, or at least 100 m ahead of the active mining face (or at least two cut widths).

Soil stripping being too close to the mining face

Soil contaminated by fly-rock

6.3.4 Supervise stripping to ensure soils are not mixed

Close supervision and monitoring of the stripping process are required to ensure that soils are stripped correctly. Common failings are stripping too little or too much. When too little, valuable rehabilitation materials are lost, and when too much, good quality soil is contaminated with poorer quality and unsuitable subsoil materials, which are frequently highly compactable and tend to cement when exposed at surface.

Risks of soil loss or contamination are particularly high when soil stripping contracts are purely issued on volume stripped, rather than on volume and quality as required by the soil stripping plan. Monitoring requires assessment of the depth stripped, the degree of mixing of soil materials and the volumes of material replaced directly or placed on stockpiles.

6.3.5 *Strip soils only when moisture content will minimise compaction risk*

Most South African soils, other than the vertisols, are highly susceptible to compaction.

Compaction is usually greatest when soils are moist, so soils should be stripped when moisture content is below the plastic limit for that soil (usually a moisture content of 5% below the plastic limit is advisable). Stripping and replacement of soil should be done during the dry winter months when rainfall is at its lowest and soils are dry and have a moisture content below their plastic limit.

Again, stripping soils during the dry months is not always practical, and some soils have to be moved when wet. In this case, every effort must be made to minimise the volume of soil handled.

6.3.6 *Strip and replace soil in one continuous process wherever possible*

Wherever possible, stripping and replacing of soils should be done as part of one process. This is both to reduce compaction and also to increase the viability of the seed bank contained in the stripped surface soil horizons. Stockpiling both increases compaction and decreases the viability of the seed bank and should only be done when no areas of reshaped spoils are available for direct placement.

6.3.7 *Use a shovel and truck fleet in preference to bowl scrapers*

Compaction is the single biggest limitation to the re-establishment of land use capability of rehabilitated soils and remains a focus of significant research effort. The prevention of soil compaction prevention during soil handling should be a priority focus for all rehabilitation activities.

The degree to which soils become compacted during stripping is largely dependent on the equipment used. Wherever possible, soils should be stripped using shovel (backhoe) and truck equipment. Best practice is to have backhoes, working on virgin ground, strip usable soils that are then loaded onto trucks that travel only on subsoil benches in areas that have already been stripped.

Bowl scrapers are designed for creating roads or building dams but are far from ideal for stripping and replacing soils, because they often cause irreversible compaction. They are, however, still frequently used in the South African mining industry to move soils, particularly from stockpiles to rehabilitation backlog areas. When used, their compacting effect can be reduced to some extent by only stripping and replacing soils when dry, by maximising the thickness of soil layers placed per run, and by running along the same wheel tracks.

Bowl scraper stripping soil

Stripping and replacement using shovel (backhoe) and truck

6.4 Monitoring criteria and relinquishment parameters

The following monitoring criteria could be used to define achievement of rehabilitation success. Parameters for setting associated relinquishment criteria are also provided.

		Relinquishment parameters
Monitoring Criterion1	• Confirm implementation of a site-specific soil stripping and handling plan, informed by a pre-stripping soil survey.	• Delineation of stripped soil – location, area (*ha*), volumes (m^3), depth (*m*) aligned to soil stripping and handling plan.
Monitoring Criterion 2	• Compare the total volume of soil stripped with the volume of soil available for stripping (to control under-stripping and soil loss, or over stripping and loss of soil quality).	• Percentage (%) of soils stripped, per horizon.
Monitoring Criterion 3	• Determine the percentage of fly rock 'contamination' of stripped soils with other horizons.	• Percentage (%) 'contamination' of stripped soils with other horizons.
Monitoring Criterion 4	• Record the volumes of stripped soils stockpiled, and document why they were not placed directly on reshaped areas available for rehabilitation.	• Alignment of mine plan and surface landform design.
Monitoring Criterion 5	• Time of the year during which stripping takes place (and moisture content of soils when stripped).	• Soils stripped only in dry season – time of the year; rainfall at that time (*mm*).
Monitoring Criterion 7	• Check that appropriate soil stripping equipment is being used by conducting regular inspections – and if not, enforce the soil stripping procedure/plan	• Use of equipment / machinery to move soils (*type, function, use*)

7. SOIL STOCKPILING

7.1 Context

Stockpiling for short periods of time (e.g. three months) significantly reduces the loss of viable seeds. Stockpiling of soils should be minimised, as far as possible, with the direct replacement of all stripped material being preferred and encouraged. Where direct replacement is not possible, soils should be stockpiled in suitable locations, in an appropriate stockpile configuration.

Soils with significantly different characteristics should be stockpiled separately. As a minimum, soils should be segregated into two categories of stockpile, namely: the heavy black clayey wetland soil stockpiles; and the well-drained red and brown/yellow soil stockpiles. Best practice would be to separate the red and yellow/brown stockpiles, so that the more productive red soils could be replaced to crest areas and the yellow/brown soils to midslope areas.

Soils that have been in stockpiles for up to 20 years have provided a reasonable growth medium, as long as proper remediation techniques (tillage, fertilisation) have been applied to the rehabilitated soils. Nevertheless, the rehabilitation objective must be to minimise the quantity of soil stockpiled, the time it is stockpiled and the number of times it is rehandled.

7.2 Rehabilitation objectives

The following rehabilitation objectives should guide soil stockpiling:

Objective 1	To minimise the quantity of soil stockpiled.
Objective 2	To limit the time stripped soils are stockpiled.
Objective 3	To limit the number of times stripped soils are re-handled.
Objective 4	To stockpile soils by end-tipping (and increase stockpile height using shovel, if necessary), to minimise compaction.
Objective 5	To fertilise and revegetate stockpiled soils to maintain soil fertility and reduce soil loss via erosion.

7.3 Actions

The following actions should be implemented to ensure appropriate soil stockpiling:

Action 1	• Locate and manage soil stockpiles so that re-handling is minimised.
Action 2	• Ensure stockpiles are located outside of drainage lines and are placed in free-draining areas so as to minimise waterlogging and soil erosion losses.
Action 3	• Minimise compaction during stockpile construction.
Action 4	• Design stockpiles to maintain a maximum level of biological activity.
Action 5	• Revegetate to condition the soil and avoid erosion losses.
Action 6	• Ensure that stockpiled soil is only used for its intended purpose/s.

7.3.1 Locate and manage soil stockpiles so that re-handling is minimised

Soil stockpiles should not be moved after construction unless the soil is being replaced in its final location in the rehabilitated landscape. Increased handling of soils degrades soil structure, increases the amount of organic carbon lost, and ultimately increases soil compactibility. Soil losses occur with each re-handling and the additional cost in moving this material is considerable.

While it may cost more initially, it is better to place stockpiles where they will not have to be moved. There will always be some soil that has to be stripped before any rehabilitated areas are available for direct placement, for example, where soils are stripped for roads, infrastructure and box-cut development during construction. These soils would need to be stockpiled, preferably as close as possible to where they are going to be ultimately used.

7.3.2 Ensure placement in a free-draining location to minimise erosion loss and waterlogging

Placing soil stockpiles in drainage lines has two major harmful effects: the soils become waterlogged and lose desirable physical and chemical characteristics; and there is a risk of soil loss due to scouring erosion at the toe during stormflow events. Ideally, stockpiles should be placed on a topographical crest which provides free drainage in all directions. Alternatively, a side- slope location with suitable cut-off berm constructed on upslope is acceptable.

7.3.3 Minimise compaction during stockpile construction

Soils should be stockpiled loosely, as far as possible, with no construction vehicle moving over any tipped soils. If shovel and truck equipment is used, the ideal is for soils to be stockpiled in a single lift. The use of heavy equipment over soil piles results in soil structure damage.

If direct dumped soil piles are too low, then it is possible to increase stockpile height using a dozer blade or back actor bucket to raise the materials. Running trucks over the piles or using a bowl scraper or grader to level and shape stockpiles, is not recommended. When the only alternative to losing soil material is the use of unsatisfactory (i.e. bowl scraper) equipment, compaction damage can be reduced to some extent by stripping as thick a cut as possible and by dumping it as thickly as possible. In addition, deposition in a single-track line may reduce to some extent the overall compaction of the dumped or replaced soil.

7.3.4 Design stockpiles to maintain maximum level of biological activity

To maintain a maximum level of biological activity in soil stockpiles, they should be constructed to provide the maximum surface area and should be vegetated (grassed) if the soil is not planned to be used within 6 months. Space constraints imposed by site factors will generally dictate the overall size and shape of the stockpiles. However, if possible, the average height should be 2 m, with a maximum height of 3 m, placed to the angle of repose (37°).

7.3.5 Revegetate to condition soil and avoid erosion losses

Establishing a good vegetation cover on soil stockpiles will maintain biological activity and reduce soil erosion on slopes. If soil stockpiles have been created by loose tipping, it would be preferable to plant and fertilise the piles by hand. Loose materials are in any event less susceptible to water erosion, though they may be more susceptible to wind erosion.

If the direct placement of usable soils is not possible, and where stockpiles have been constructed in several lifts and the soils have been compacted by dump truck wheel pressure, the following steps should be followed to keep the soil in good condition for later use:

- Rip the stockpile surface with suitable machinery to relieve surface compaction, aerate the soil; and encourage deep rooting of revegetated plants;
- Sow the ripped surface immediately with low-maintenance species, such as dwarf grasses, to prevent erosion and gully formation; and
- Apply ongoing maintenance to the stockpile surface (re-seeding in areas of vegetation die-back, chemical amelioration aligned to soil assessments, and weed control).

7.3.6 Ensure that stockpiled soil is only used for its intended purpose/s

Once established, stockpiles should be managed to ensure that losses from the piles are minimised and that no additional damage to the physical, chemical or biotic content occurs. There are several potential agencies that can harm stockpiles, and these include water and wind erosion, illicit "borrowing" for other purposes, contamination by coming into contact with mineral waste or polluted mine water, and water logging.

Ensure that stockpiled soil is only used for its intended purpose. One of the greatest causes of loss of topsoil, when stockpiles are in situ for a long period, is their use for other purposes. Frequently they will be used for construction purposes (e.g. raising pads or foundation levels, creating berms, etc.). This occurs most frequently when stockpiles are not monitored regularly and when stockpiles are not clearly demarcated with warning signposts.

The main contamination risks for soil stockpiles are the dumping of mineral waste materials next to, or on top of, the stockpiles, contamination by fly-rock from blasting, and the pumping out of contaminated waters from the pit that then come into contact with the stockpiles. A detailed management and monitoring program, and an employee awareness program, will significantly reduce the risk of stockpile "robbery" and/or contamination.

7.4 Monitoring criteria

The following monitoring criteria could be used to define achievement of rehabilitation success during soil stockpiling. (No parameters for setting associated relinquishment criteria are provided as these stockpiles should only have a temporary place in the operational landscape. At closure, only those soil stockpiles retained for ongoing care-and-maintenance will still be on-site, and these will be managed as part of the Post-Mining Land Management Plan).

Monitoring Criterion1	Materials balance is available that includes stockpile soil types, volumes and locations.
Monitoring Criterion 2	Dedicated construction designs exist for soil stockpiles.
Monitoring Criterion 3	Appropriate equipment has been used for stockpile construction
Monitoring Criterion 4	Soils of different types (upland and bottomland soils) been stockpiled separately.
Monitoring Criterion 5	Stockpiles are located in areas that are protected from contaminating materials and/or polluted water.
Monitoring Criterion 6	Stockpiles are located in areas where they will not become waterlogged.
Monitoring Criterion 7	Stockpiles are protected from upslope runoff by construction of bunds or trenches.
Monitoring Criterion 8	Stockpiled soils are revegetated, and soils are ameliorated as required whilst stockpiled.

8. SOIL REPLACEMENT

8.1 Context

Soil, when placed over reshaped subsoils and backfill on the rehabilitated landscape, provide plants with a rooting medium that stores nutrients and water, provides a medium for anchorage, and a barrier between the roots and the potentially harmful elements that may be present in the underlying substrates, such as coal spoils.

Once the final surface landform has been created, soil replacement can begin. The optimal timing of soil replacement is a matter for debate, because in many instances the recreated landform is subject to ongoing settlement for some years after the reshaping has been completed. This resettlement, theoretically, accelerates after final pit closure due to the re-establishment of water tables, the wetting of the backfilled spoil, and the consequent repacking and compaction of the backfilled materials. This may result in significant surface irregularity in relation to the agreed final landform and may result in impeded drainage and surface soil waterlogging issues. However, on balance, early replacement of soil is the desired option as it should minimise the need for stockpiling soil by increasing the proportion of stripped soil that can be replaced directly.

Replacement of topsoil

Photos: P. Tanner 2007

Benefit from topsoiling and fertilisation – good growth

Compaction is the greatest single problem which limits the effectiveness of rehabilitation in South Africa today. Ideally, soil horizons should be stripped from the top down and be replaced in their “original” sequence. However, this is a theoretical ideal and no mining equipment would be able to do this without detrimentally compacting the underlying soils as the next layer is placed. This approach can lead to multiple compacted layers in the recreated soil profile.

Usable soils stripped ahead of mining are preferably live-placed by end-tipping onto reshaped spoil areas to provide the correct soil depth to meet land capability commitments. This also means that the right type of soil will be placed at the correct position in the landscape (wetland soils in low lying areas, and better drained red and yellow/brown soils are placed on crest and midslope areas).

The correct spacing of the end-tipped soil piles must be carefully controlled to ensure that when spread with a suitable dozer, the planned soils depths (to meet land capability targets) are achieved. Once spread, additional soil cannot be supplemented without moving over the placed soils resulting in unwanted compaction.

8.2 Rehabilitation objectives

The following rehabilitation objectives should guide soil replacement:

Objective 1	To minimise the loss of replaced soils.
Objective 2	To replace different soils types in their correct catenal position on the recreated land surface.
Objective 3	To minimise compaction during soil replacement.
Objective 4	To replace soils of the right type, to the correct depth, to achieve planned land capability targets.
Objective 5	To ensure sufficient soil is kept in stockpiles for longer term care-and-maintenance activities on rehabilitated land.

8.3 Actions

The following actions should be implemented to ensure appropriate soil replacement:

Action 1	• Replace different soil types in their correct catenal positions.
Action 2	• Retain a soil reserve to repair localised surface subsidence areas and soil cover losses.
Action 3	• Minimise compaction of replaced soils (during replacement).

8.3.1 Replace different soil types in their correct catenal positions

As far as possible, soils should be replaced in similar positions in the re-created slope to those they occupied on the original slope. Thus, red and yellow/brown soils belong on the crest and upslope areas, while grey soils with hydromorphic characteristics belong on the lower slopes and dark hydromorphic clays belong in the bottom lands. This is required so that the replaced soils encounter moisture conditions suited to their physical and chemical characteristics.

Even distribution and depth of usable soils placed over backfilled spoils – enabled by a materials balance against which rehabilitation was undertaken

8.3.2 Retain a soil reserve to repair localised surface subsidence areas and soil cover losses

As rehabilitated land is prone to differential settlement, it is important to retain a stockpile of soil material to fill in the depressions (melon holes), both to prevent ponding and water logging, and to maintain a free draining surface.

Soil reserves may also be needed to fill-up surface erosion or gullies that could form across the replaced soil covers. If the surface landform has been designed and implemented properly, and a suitable vegetation cover is in place, this erosion should be limited. However, some care-and-maintenance is usually required as the vegetation cover establishes, and as the land settles.

The quantity of soil that should be retained for such repair work will differ, depending on the susceptibility of the rehabilitated profile to 'slumping' over time and is best derived from practical experience. In the initial phases of rehabilitation, however, where such knowledge does not exist, 1 - 5% of total soil stripped should be retained for repair work.

Subsided surfaces that have become waterlogged

8.3.3 Minimise compaction of replaced soils

Compaction is the greatest single factor limiting the effectiveness of replaced soils, and this is usually caused by inappropriate replacement methods, applied at inappropriate times.

Move soils when dry

Soils should only be handled during the dry season, or when their soil moisture content is at least 3 – 5% below their plastic limit (PL), to provide a margin of 'safety' in preventing soil damage/compaction. For example, Hutton soils have a PL of 15 (15% moisture content). Assuming a 3 – 5 % safety buffer, stripping and replacement of these soils would need to take place when its moisture content is 10 – 12%. Clay soils with a PL of 23 can be moved safely with a moisture content twice that of well-drained soils (i.e. clays hold more moisture and move out of their plastic range at a higher moisture content).

Use appropriate equipment

Equipment used to replace soils has a major effect on compaction levels. The ideal is the use of soil spreading methods that do not involve heavy machinery traffic over areas where soils have been replaced.

At present, soil replacement in South Africa is limited to the use of dump truck or bowl scraper equipment. Dump trucks are preferred because they can end-tip soils into loose (uncompacted) piles that are then spread using a suitable LGP dozer. Bowl scrapers are unsuitable because they run directly over the soils being replaced, causing wheel-track compaction. This occurs mainly where deeper soils are required (usually arable potential), and where compaction should be especially avoided. Bowl scrapers will have less impact where shallower soils (grazing potential) are required, and where soils can be placed sufficiently deep in a single run to meet the required soil depth after dozer spreading.

After soil replacement, initial smoothing of the rough soil surface is typically done by dozer, which is the preferred equipment to use because its tracks exert a lower bearing pressure on soils than trackless (wheeled) equipment. Graders should be avoided for soil spreading and smoothing because their tyres exert significant ground pressure and may cause irreversible compaction.

Replace soils to the planned thickness in single lift

With truck deposition, the full thickness of soil required can be replaced in a single lift, with no need for the heavy vehicles to travel over the replaced soil material. However, replacement by truck requires careful management to ensure that the correct volumes of soil are replaced. The depth of the final soil will depend of the size of the dump trucks used and the spacing of the end-tipped soil piles. A dozer is normally used to spread the piles and to "smooth" the surface prior to re-establishment of vegetation.

Bowl scrapers are seldom capable of replacing more than 250 mm of soil in a single lift and typically will require multiple runs to replace the full thickness of soil required. For arable land, which requires more than 600 mm of soil, at three runs would be needed, with the wheel tracks compacting already placed soil.

Create multi-layer soil profiles mimicking pre-mining profiles

While multi-layer replacement is the ideal from the chemical and biotic viewpoint, it is the worst option from the compaction point of view, as each layer has to be deposited and levelled prior to the next layer being replaced – all of which increases compaction. Compaction can be reduced by correct use of equipment, minimising travel over the re-created profile (to some extent), but also by only moving soils when they are dry.

There are limited known cases in South Africa of large-scale rehabilitation where a deliberate effort has been made to replace soil materials in the same sequence as they occur in nature. However, this sequential soil replacement would result in significant benefits in the re-establishment of the natural soil fertility recycling processes. The outcome is an organic-enriched, chemically fertile, upper soil zone located in the zone of maximum plant root exploitation.

Where the rehabilitation objective is to establish natural revegetation (e.g. to enhance biodiversity), and where soils have been stripped and replaced directly with the seed-containing horizons on top, there should be no requirement for seed-bed preparation or seeding. However, most soil stripping and replacement activities result in the mixing of top- and sub-soil, which dilutes the seed bank and soil nutrients, making fertilisation and overseedng essential.

Highly compacted soil surface smoothed by a graded

Replaced soil being smoothed by a dozer – the preferred method

Scarify the soil-spoil interface

In practice, significant compaction can be expected on the surface of the reshaped spoils, creating an impermeable boundary at the soil-spoil contact. Disturbance and some mixing at the soil-spoil interface is important for keying the soil into the spoil (important on slopes), and to establish hydraulic continuity between the two.

APPENDIX

Appendix I:
Considerations for soil compaction and its alleviation
(MinCoSA, 2007)

8.4 Monitoring criteria

The following monitoring criteria could be used to define achievement of rehabilitation success during soil replacement:

Monitoring Criterion1	• A post-mining soil survey, aligned to the upfront soils handling plan, indicates: – Achievement of planned land capability targets (soil depth and slope); – Measured erosion rates meet predefined limits (derived from in situ trials or calculated from the Universal Soil Loss Equation or a similar agreed method); and – Degree of compaction of replaced soils, to inform the level of effort needed for ripping for compaction alleviation.
Monitoring Criterion 2	• A post-mining assessment of designed rehabilitation surface profiles has been undertaken, that indicates: – If the rehabilitated landform matched the planned landform; and – Whether the rehabilitated surface is free draining (provided this is a rehabilitation objective).
Monitoring Criterion 3	• Correct equipment was used to place and spread the soils.

9. SOIL AMELIORATION

9.1 Context

Rehabilitated soils are, in most cases, inferior to the natural profile (due to compaction, mixing of topsoil with subsoil horizons, etc.). As a result, they are less satisfactory as a plant growth medium, having lower organic matter content, reduced chemical fertility, degraded physical condition and depleted microbial populations.

Soil amelioration is a long-term investment into the foundation of rehabilitation success. It is the one opportunity to ensure that sufficient ameliorant is incorporated into the replaced soil. The importance of good soil amelioration can be measured in the vegetation's improved growth response, under favourable climatic conditions (precipitation, temperature, etc.). When good soil amelioration is conducted, and vegetation growth is stimulated, soils are bound more quickly by plant roots, resulting in reduced soil erosion.

Replaced soils will always require physical and chemical amelioration, and often require biological amelioration as well (Figure 15).

Figure 15: Summary of physical, chemical and biological soil properties important for plant growth

9.1.1 *Physical properties*

'*Soil texture*'[29] is the relative proportions of sand, silt and clay. These particles differ from each other in terms of particle sizes. The size of sand particles range between 2.0 and 0.05 mm; silt, 0.05 mm and 0.002 mm; and clay, less than 0.002 mm. This difference in size is largely due to the type of parent material and the degree of weathering. Sand particles are generally primary minerals that have not undergone much weathering; clay particles are secondary minerals that are the products of the weathering of primary minerals. As weathering continues, the soil particles break down and become smaller and smaller.

The *soil textural class* is a grouping of soils based upon these relative proportions of sand, silt and clay. As mentioned above, soils with the finest texture are called clay soils, while soils with the coarsest texture are called sands. However, a soil that has a relatively even mixture of sand, silt, and clay and exhibits the properties from each is called a loam. There are different types of loams, based upon which soil particle is most abundantly present.

Soil texture is used in classification of soil. If the percentages of clay, silt, and sand in a soil are known (primarily through laboratory analysis), you can use the textural triangle to determine the texture class of your soil (Figure 16)[29].

Soil texture has an important role in nutrient management because it influences nutrient retention. For instance, finer textured soils tend to have greater ability to store soil nutrients.

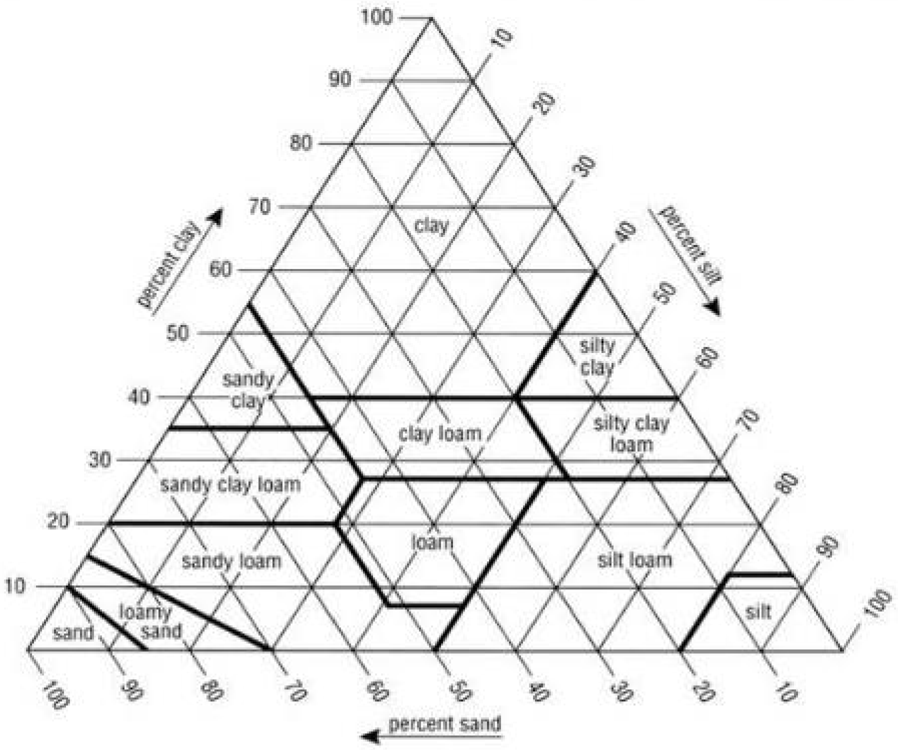


Figure 16: Soil Textural Triangle (describing the relative proportions of sand, silt and clay in various types of soils)

[29] http://soils.usda.gov/technical/manual/print_version/complete.html

'*Soil structure*' is the arrangement - shape, size and orientation, of soil particles with respect to one another[30]. If particles are closely packed then soil will have low void ratio, and vice versa. Soil structure influences permeability, compressibility, shear strength, etc.

Soil groupings are called peds or aggregates, which often form distinctive shapes typically found within certain soil horizons. For example, granular soil particles are characteristic of the surface horizon. *Soil aggregation* is an important indicator of the workability of the soil. Soils that are well aggregated are said to have "good soil tilth." Generally, only the very small particles form soil aggregates, which includes silicate clays, volcanic ash minerals, organic matter, and oxides. There are various mechanisms of soil aggregation, including soil microorganisms excreting substances that act as cementing agents to bind soil particles together; extension of fungi filaments (hyphae) into the soil which 'tie' soil particles together, and excretion of mineral-binding sugars in the soil by roots. Soil particles may also be naturally attracted to one another through electrostatic forces, much like the attraction between hair and a balloon.

The various types of soil structures are provided in Figure 17[30].

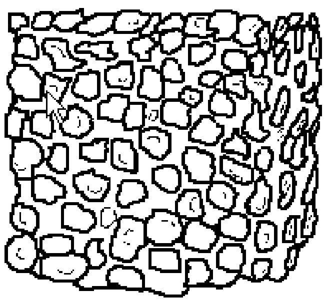
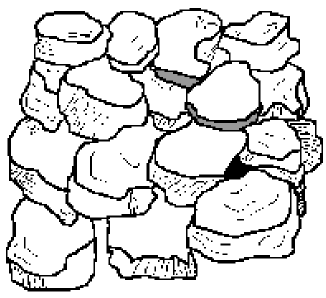
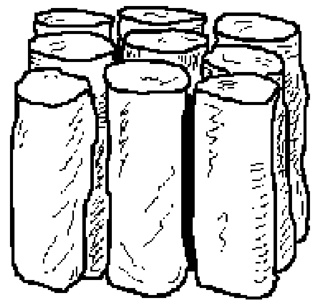
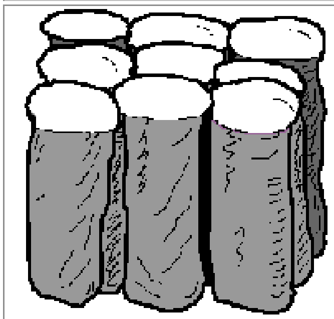
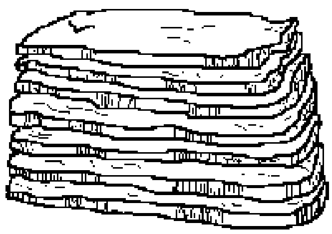
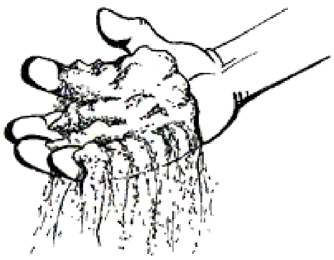
		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

Figure 17: Types of soil structures

[30] http://www.cst.cmich.edu/users/Franc1M/esc334/lectures/physical.htm

'*Bulk density*' (BD) is a measure of soil compaction and soil quality. It affects rainfall infiltration, plant rooting depth, water holding capacity, soil porosity, plant nutrient availability, and soil macrofauna and biota activity, which influence key soil processes and productivity. It is the weight of dry soil per unit of volume, typically expressed in g/cm^3. Inherent factors that affect bulk density, such as soil texture, cannot be changed. Bulk density is dependent on soil organic matter content, the density of soil minerals (sand, silt, and clay), and their packing arrangement. As a rule of thumb, most rocks have a density of 2.65 g/cm^3 so ideally, a silty loam soil has 50% pore space and a bulk density of 1.33 g/cm^3. Generally, loose, well-aggregated, porous soils, and those rich in organic matter have lower bulk density. Sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils. In natural soils, bulk density typically increases with soil depth because subsurface layers are more compacted, have less organic matter, and less aggregation of particles. However, in rehabilitated and agricultural land, there may be a zone of maximum density at the plough shear or cultivator level, followed by lower bulk densities deeper down.

Bulk densities above the thresholds shown in the following table (Table 4) impair root growth.

Table 4: General relationship between soil bulk density and root growth, based on soils with different textures

Soil texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that affect root growth (g/cm^3)	Bulk densities that prevent root growth (g/cm^3)
Sandy, loamy soils	< 1.60	1.69	> 1.80
Sandy soils, Sandy loam soils	< 1.40	1.63	> 1.80
Sandy clay loams	< 1.40	1.60	> 1.75
Silts, Silty loams	< 1.40	1.60	> 1.75
Silty clay loams	< 1.40	1.55	> 1.65
Sandy clays, Silty clays, Clay loams	< 1.10	1.49	> 1.58
Clays (45% clay)	< 1.10	1.39	> 1.47

From the physical perspective, the actions of soil removal, stockpiling and replacement result in high levels of soil compaction. Consequently, there is a need for virtually all reconstituted profiles to be loosened.

9.1.2 Chemical properties

Plants obtain nutrients from two natural sources: organic matter and minerals. The following are key soil fertility elements – nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulphur (S) and zinc (Z). N, P and K are considered macro-elements.

From a chemical perspective, the stripping of the surface soil (topsoil) in a single, organic-rich layer results in the dilution of the fertility, when nutrients that are typically concentrated in the surface few centimetres, are mixed with the underlying 300 - 400 mm of relatively impoverished soil material. The situation is worsened in those cases where topsoil and subsoil are mixed, or where subsoil alone is replaced. Improvement of a soil's chemical properties will require consideration of the following:

- pH

  Soil pH is a measure of active soil acidity and is the most commonly used indicator of mine soil quality. The pH of a given mine soil can change rapidly as pyritic rock fragments weather and oxidise. Pyrite (FeS_2), when present, oxidises to sulfuric acid and drastically lowers the pH, while dolomite and calcite ($Ca/MgCO_3$) tend to increase the pH as they weather and dissolve.

  Vegetation achieves optimal growth in soil at a neutral pH. A mine soil pH range of 6.0 to 7.5 is ideal for forages and other agronomic or horticultural uses[31].

Photos: R. Hattingh 2017

Low soil pH values that, if left unmanaged, can result in significant vegetation die-back

- Macronutrients

  Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) are key macronutrients affecting plant growth.

  Successful crop production or pasture performance on rehabilitated land requires sufficient levels of plant macronutrients in the soils. Generally, rehabilitated soils have suboptimal levels of macronutrients as a result of over-stripping, soil stockpiling or tillage. This requires correction at the time of

[31] *Pers. comm.* (2018): Dr Phil Tanner.

rehabilitation, and in subsequent years. The rehabilitation maintenance programme must cater for ongoing fertiliser application (as determined by soil analyses) to ensure that soil fertility improves over time to achieve target levels to support sustainable plant growth into the future.

Phosphorus

Phosphorus is a key macronutrient because it is a major component in plant DNA and RNA (nucleic acids). It is critical for root development, crop maturity and seed production.

Most rehabilitated soils in Mpumalanga are strongly deficient in phosphorus, mainly as a result of the naturally low phosphorus levels in these soils; but also because of the 'dilution' effect that lowers phosphorus concentration during mixing when the usable soil profile is stripped ahead of mining.

The phosphorus content of rehabilitated soils can be measured in an agricultural soils laboratory (Bray 1 or 2 method) and will expose any deficiency that will need to be addressed by appropriate fertiliser application rates. Phosphorus is usually added to soils as a phosphate fertiliser, which can be sourced commercially as single superphosphate, rock phosphate, or as a phosphate component of an NPK composite fertiliser.

Potassium

Potassium has an essential indirect role in plants in that it is required for the activation of over 80 enzymes critical to the plant's metabolism. It improves a plant's ability to withstand temperature extremes, water stress and pests. This element increases water use efficiency and transforms sugars to starch in the grain- (seed) filling process.

Nitrogen

Nitrogen is an essential nutrient for plant growth, development and reproduction. Despite nitrogen being one of the most abundant elements on earth, nitrogen deficiency is probably the most common nutritional problem affecting plants worldwide. Nitrogen from the atmosphere and earth's crust is not directly available to plants, and so must be assimilated into plant-available nitrate (NO_3) through the microbial processes of nitrogen fixation, ammonification and nitrification. Nitrogen is so vital because it is a major component of chlorophyll, the molecule by which plants capture sunlight energy to produce sugars from water and carbon dioxide (i.e. photosynthesis). It is also a major component of amino acids, which are the building blocks of proteins. Without proteins, plants wither and die[32].

[32] https://www.cropnutrition.com/efu-nitrogen (accessed 26 September 2018).

Calcium, magnesium and sulphur[33]

Calcium, magnesium and sulphur are essential secondary plant nutrients, so-called because they are required in smaller quantities than nitrogen, phosphorus and potassium.

The primary functions of Ca in plants are to provide structural support to the cell walls and to activate specific plant enzymes that coordinate plant growth processes. For optimal vegetation growth, rehabilitated soils need sufficient levels of both calcium and magnesium, and in the appropriate ratio (typically between 5:1 and 8:1).

In the soil, calcium is essential in maintaining soil structure by flocculating clays and organic matter, thereby increasing soil porosity, and improving air and moisture movement through the soil. This promotes soil biology and enhances root growth.

Calcium and magnesium are also essential, not only for regulating soil acidity but also as a nutrient element necessary for normal plant growth.

Magnesium is a key element (along with nitrogen) of the chlorophyll molecule, involved in photosynthesis. It also serves as an activator for many plant enzymes required for growth processes and stabilises nucleic acids. Magnesium deficiencies, revealed during soil analysis, can be corrected using dolomitic (as opposed to calcitic) lime, or magnesium sulphate if a sulphur deficiency also needs to be addressed.

Sulphur is needed in fairly large quantities by plants, so rehabilitated soils deficient in sulphur will need to receive supplementary sulphur. Sulphur is also an essential building block in chlorophyll development and protein synthesis.

- Micronutrients

Boron (B), manganese (Mn), iron (Fe), zinc (Zn), nickel (Ni), molybdenum (Mo), copper (Cu), and chloride (Cl) are key micronutrients essential for plant growth. A deficiency in any one of the micronutrients in the soil can limit plant growth, even when all other nutrients are present in adequate amounts.

- Organic carbon content

'*Organic matter*' includes any plant or animal material that returns to the soil and goes through the decomposition process. *Soil organic matter* (SOM) - the product of on-site biological decomposition - affects the chemical and physical properties of the soil and its overall health. Its composition and breakdown rate affect the soil structure and porosity; the water infiltration rate and moisture holding capacity of soils; the diversity and biological activity of soil organisms; and plant nutrient

33 http://extension.msstate.edu/publications/secondary-plant-nutrients-calcium-magnesium-and-sulfur

availability. Nutrient exchanges between organic matter, water and soil are essential to soil fertility and need to be maintained for sustainable production purposes.

All newly rehabilitated mine soils, and many older ones, will require significant fertiliser applications for the establishment and maintenance of any plant community. Organic matter is the major source of nutrients such as nitrogen, and available P and K in unfertilized soils. A level of organic carbon greater than 0.75%, through depths of 250 mm, indicates good fertility[34]. Normal, well-drained soils within the Mpumalanga area (and excluding wetlands) will contain < 2 % organic carbon content. However, "about 58% of all South African soils have less than 0.5% organic C, and only 4% have more than 2% C"[35].

9.1.3 Biological properties

From a biological perspective, improvement of a soil's biological properties will require consideration of soil microbes (bacteria and mycorrhizal fungi) and soil fauna. Soil microbes include several bacterial species active in the decomposition of plant material as well as fungal species whose symbiotic relationship with many plants facilitates uptake of nitrogen and phosphorus in exchange for carbon.

Both the microbes and fauna play a major role in aggregate stabilisation, which is important for maintaining suitable structural conditions for cultivation and porosity for optimal crop growth[36].

Although experience indicates that mycorrhizal fungi inoculation has value for rehabilitation purposes, research demonstrating this value is currently limited, and the best way of harnessing the desirable qualities of mycorrhizal fungi have yet to be determined.

9.2 Rehabilitation objectives

The following rehabilitation objectives should guide soil amelioration:

Objective 1	To optimise soil conditions conducive to improved soil structure.
Objective 2	To optimise soil conditions that enhance germination, facilitate root development and vegetation growth.
Objective 3	To improve water and nutrient use efficiency of vegetation.

[34] Ghosh, A.B., Bajaj, J.C., Hassan, R., and Singh, D. (1983): Soil and water testing methods - a laboratory manual, IARI, New Delhi, 31-36.
[35] Du Preez *et al* (2011): Land Use and Soil Organic Matter in South Africa 1: A Review on Spatial Variability and the influence of Rangeland Stock Production. South African Journal of Science 107 (5-6). May/June.
[36] Ghose, M.K. 2005. Soil conservation for rehabilitation and revegetation of mine-degraded land. TIDEE – TERI, Information Digest on Energy and Environment, 4(2), 137-150.

9.3 Actions

The following actions should be implemented to guide appropriate soil amelioration:

Action 1	• Following soil placement, apply lime and superphosphate fertiliser (as required) and rip all soils to the full depth of the replaced soil layer.
Action 2	• Apply and incorporate - by discing, any additional chemical ameliorants required (N & K fertilisers), to condition soil for optimal plant growth.
Action 3	• Till the soils to produce a seed-bed suitable for the plant species selected for seeding.
Action 4	• Top dress with appropriate fertiliser, especially nitrogen, as growth proceeds.
Action 5	• Undertake a post-placement soil fertility and compaction assessment to determine subsequent (following season) amelioration needs.

9.3.1 Following soil placement, apply lime and superphosphate fertiliser (as required) and rip all soils to the full depth of the replaced soil layer

While a range of other methods for the amelioration of compaction have been suggested (for instance, use of plants with greater root penetration abilities, or use of organic ameliorants) to date in the South African context, deep ripping with appropriate equipment remains the sole method of effectively reducing compaction.

Ripping technology is well known in the agricultural industry. However, the degree of compaction and the depth to which compaction is achieved in the mining industry far exceed the levels of compaction normally found in agricultural soils. In addition, the surface of the underlying spoil or overburden material is usually also compacted, and the soil/spoil interface also frequently acts as an impenetrable barrier to deep root penetration. The requirement, then, is to rip through the overlying soil material and into the underlying spoil material.

Correct soil moisture content for maximum disturbance (shattering effect) must be established during ripping, as must the desired spacing between rip lines. Due to the extreme levels of compaction encountered, ripping normally requires the use of a dozer with one or (at a maximum) two ripper tines, operating to a depth in excess of 1 m. These tines are usually mounted directly behind the dozer tracks – which again raises an issue, as the spacing between dozer tracks is usually in excess of the desirable width between rip lines. The desirable rip pattern will be determined by the “breakout” pattern of the disturbance caused by each ripper tine. The breakout usually radiates outwards and upwards at an angle of some 45^0 from the ripper tine, but the zone of soil affected (the breakout zone) can be increased by fitting wings to the ripper tines.

Sub-soil compaction compared to deep ripping (evident by the defined soil:spoil interface as compared to the underlying spoils being elevated through the cover soil profile). Deep root penetration is clearly evident where the deep ripping has taken place

Ripping must penetrate through soil into the underlying overburden materials in order to ensure free drainage and to ensure root penetration. This may result in contamination of the overlying soils by large rock fragments dragged up from the spoil layers and a number of these may end up on surface. For those rehabilitated areas that must be returned to row-crop production, the removal of large rocks, usually by hand, will be necessary. The benefit derived from decompaction and improved root penetrability far outweighs the inconvenience of stone-picking. For those areas due to revert to natural grazing, the presence of loose rock on surface should not pose a problem.

Acceptable soil bulk density values must also be determined, and progress monitored against targets.

9.3.2 Apply and incorporate - by discing, any additional chemical ameliorants required (N & K fertilisers), to condition soil for optimal plant growth

Inappropriate use of fertilisers can be detrimental to soil health and vegetation. Fertiliser application should be site-specific, with exact specifications based on the results of soil and/or land capability assessments. Fertiliser requirements (application frequency, rate and type) will be dictated by several considerations, the most important of which include the following:

- The type of vegetative cover or crop to be grown, and its growth characteristics;
- The nutrient status of the soils;

- The pH and moisture availability of the soils;
- The manner of vegetation utilisation of the fertilisers; and
- The production level or yield target that may be set, taking into account soil and climatic potential.

Despite some limitations, conventional soil analysis (soil testing) provides the best guide to application rates and a sound monitoring programme is regarded as essential for proper rehabilitation. In any fertilisation programme, a distinction must be made between basal application of fertiliser and lime designed to correct disorders and raise the fertility status to a suitable level prior to vegetation establishment, and maintenance dressings applied for the purpose of making good losses and keeping up nutrient levels. This distinction is especially relevant to rehabilitation of disturbed land where the initial deficit is likely to be greater than on comparable undisturbed agricultural lands.

Fertiliser application on rehabilitated landscapes should be applied in stages. Fertilisers are initially applied at a heavier rate (starter application) – the starter application of fertiliser is critical to maintain the necessary nutrient pool in replaced cover soils. Then, annual maintenance applications of fertiliser need to be applied for 3 to 5 years at lower application rates. These follow-up applications should be based on the results of site-specific soil analysis and land capability assessment.

Lime application

Since the neutralising effect of lime is strictly localised, application in the usual way (broadcasting and ploughing or discing in) ameliorates only the surface layer to the depth of incorporation. The acidity of deeper material will remain unaffected. Subsoil acidity is a serious problem in many Highveld soils. Deep incorporation of lime is costly and not very efficient. The possibility exists of eliminating subsoil acidity on rehabilitated sites by broadcasting lime in appropriate quantities on the soil prior to stripping. Relatively thorough incorporation should be ensured during handling and spreading operations resulting in amelioration throughout the entire depth of the new soil at very little additional cost.

Starter application of lime, prior to revegetation

Nitrogen

Water soluble forms of nitrogen (as present in most fertilisers) are highly mobile in the soil and are subject to loss by leaching and volatilisation. Consequently, the beneficial effects of a single dressing will last for a limited time only. This, together with the fact that crop requirement varies with stage of growth and climatic conditions, accounts for the recommended practice of splitting the total nitrogen application into two or more dressings (provided that each of the latter exceeds a certain minimum quantity).

The nitrogen requirement of pasture grasses during the first month after establishment is low. Under normal farming conditions, the natural supply from the soil is usually adequate and nitrogen is not applied at establishment. However, on freshly topsoiled land, vigorous early growth will be promoted by a small pre-plant application of 25 to 50 kg N per ha, irrespective of the species used. This may most conveniently be applied in conjunction with basal P and K through a suitable mixture which is broadcast and disced in during final seedbed preparation immediately prior to planting.

To avoid acidification, limestone ammonium nitrate is the preferred N carrier.

Phosphorus

Phosphorus is invariably deficient, often acutely so in acid soils of high rainfall areas.

Rehabilitated soils intended for low potential pasture production should have a phosphorus content of at least 15 mg P/kg, while for high potential pastures this level should be closer to 30 mg P/kg. Mine soils will invariably test lower than this and the deficit should be made good prior to the establishment of vegetation. Experience on the Mpumalanga mines has shown that the application of 5 kg P/ha (usually applied as single superphosphate containing 10.5% P) will increase the phosphorus content of rehabilitated soils by 1 mg P/kg (measured using the Bray-1 method)[31]. This rule of thumb may be used to calculate the basal dressing which should be in the water-soluble form.

Less soluble forms (e.g. sedimentary phosphate rock) are often recommended for basal (but not surface) application for pastures on acid soils in which case the total quantity of phosphorus applied should be doubled. To avoid damage to seed and emerging seedlings through direct contact with unreacted water-soluble P fertilisers, the latter should be applied prior to planting and must be thoroughly incorporated with the soil. All basal phosphorus applications should be thoroughly incorporated by ploughing into the plant rooting zone.

Although the phosphorus content of herbage is low (0,2-0,3 %), an annual topdressing using a water-soluble phosphorus carrier is necessary even on grazed pastures because applied phosphorus tends to become decreasingly available to plants with time. The amount required should be assessed by soil analysis and will vary with the utilization profile of the pasture. As a general guide, zero grazed pastures should receive at least 25, 35 and 40 kg of water-soluble P per hectare for low, medium and high levels of production, respectively. Legume-based pastures require 40 kg phosphorus irrespective of level of production.

Potassium

Most rehabilitated soils are deficient in potassium and will require supplementary potassium during the soil amelioration process. Clayey soils have a higher nutrient holding capacity and need higher levels of available potassium than sandy soils.

Rehabilitated soils intended for low potential pasture production should have a minimum potassium content of at least 80 mg K/kg, while for high potential pastures this level should be closer to 150 mg K/kg. The application of 5 kg K/ha (usually applied as potassium chloride containing 50% K) will increase the K content of rehabilitated soils by 1 mg K/kg[31].

Analysis is particularly important in managing soil potassium status for the following reasons: (i) fairly wide fluctuations may occur as a result of leaching (particularly on sandy soils), fixation of applied potassium by clay minerals, and pasture utilisation pattern; (ii) an oversupply of potassium is wasteful because of luxury uptake by plants; and (iii) low topsoil potassium levels may be compensated for by subsoil reserves – a phenomenon that may be particularly relevant in the case of weathering spoil.

The soil should receive a basal application designed to raise exchangeable potassium to a value of 120 ppm irrespective of subsoil reserves. In general, for zero grazing, soil levels should be kept at about 120 ppm exchangeable potassium by means of a single annual topdressing applied in the autumn to loams and clays and split into two in the case of sandy soils (< 15 % clay). In the absence of soil analysis, 150, 250, and 300 kg per hectare may be applied for low, medium and high productivity, respectively. Where spoil material is within rooting depth of the established pasture, its potassium status should be investigated as this, if high, may permit downward adjustment of the application rate determined using the above norms. Where pastures are grazed, recycling of potassium may be appreciable but will depend on the extent of occupancy. In this case potassium should be applied only on the basis of analysis.

Sulphur

In the view of the general sulphur contamination of coal mining environments through coal waste and dust, and aerosolic emissions of sulphur from coal burning power stations, sulphur deficiencies are highly unlikely to develop. Consequently, low- sulphur fertilizers (double superphosphate instead of single supers, and LAN instead of ammonium sulphate) can be used without risk of including a sulphur deficiency.

Calcium and magnesium

Calcium will not normally be limiting in well-fertilised pastures (due to additions through phosphatic fertilizers) but magnesium may fall below the threshold of 50 ppm. This may be rectified by the use of dolomitic lime or potash magnesia.

Minor elements

Molybdenum is the only minor element to limit growth on acid soils. Legume seed must be given a standard treatment of sodium molybdate equivalent to not more than 300g of molybdic acid applied to the quantity of seed used per hectare

APPENDIX

Appendix J:
Considerations for soil fertilisation and liming
(MinCoSA, 2007)

An adaptive land management approach greatly influences the levels of applied plant nutrients (N:P:K) retained by the soil. Cutting and baling results in an "export" of all nutrients from the land, while grazing contributes to the retention of organic matter and nutrients in excrement and urine, all of which accelerates the recycling of nutrients on rehabilitated land and the build up of organic material and soil microbial communities. Although controlled burning is a useful means of managing pastures when grazing is not an option (i.e. where rehabilitated land is too close to operational areas), it is wasteful in the sense that biomass and N are lost - though P and K, and some additional microelements are retained (in the ash). Ongoing land management is required on rehabilitated mined land, and that supplementary applications of fertiliser (determined by laboratory analysis) will be required to achieve target soil fertility values to sustain pastures in the long-term.

9.3.3 Till the soils to produce a seed-bed suitable for the plant species selected for seeding

For those rehabilitated areas that are due to return to agricultural use, generating a tilth suitable for vegetation establishment relates principally to the need for the establishment of improved pastures or row-crops. In some cases, natural revegetation will be permitted to occur and, provided the natural surface horizons have been returned in the correct sequence and the surface layer was stripped and returned directly, there may be no need to undertake the procedures of generating a seedbed tilth. In this case, the rough surface left after ripping should not be subjected to further tillage. Items of equipment needed to establish the appropriate tilth include spring-tine harrows and disc harrows. Standard agricultural equipment and techniques are appropriate for this activity.

9.3.4 Top dress with appropriate fertiliser, especially nitrogen, as growth proceeds

Pasture plants other than legumes require a continuous supply of nitrogen from the soil during the period of active growth if vigour and palatability are to be maintained. A nitrogen budget should be worked out as described earlier and the pasture top dressed with split applications starting one month after emergence and terminating about six weeks before the anticipated end of the growing season. Grass-legume pastures that are grazed do not require regular nitrogen applications. They should however be kept under observation for signs of nitrogen deficiency. Zero grazed grass-legume pastures may have a small requirement of the order 100 kg.

9.3.5 Undertake a post-placement soil fertility and compaction assessment to determine subsequent (following season) amelioration needs

Replaced soils have been significantly altered physically, chemically and biologically. However, experience indicates that most mines undertake pre-mining soil assessments, and then base their rehabilitation specifications on this pre-mining context. This is sure to result in sub-optimal or failed rehabilitation.

Once soils have been replaced in the rehabilitated landscape, a dedicated post-placement soil analysis and soil compaction assessment should be undertaken, aligned to the predefined post-mining land capability and associated land use requirements. The results of this assessment will dictate any further physical amelioration approaches required, chemical ameliorant (fertilizer, lime, etc.) application rates and/or biological amelioration needs.

As the rehabilitated landscape changes and improves over time, regular follow-up assessments should be undertaken to inform follow-up care-and-maintenance needs (see Section C: Ongoing Land Management).

APPENDIX

Appendix H:
Sampling for soil analysis (post-placement soil assessment)
(MinCoSA, 2007)

9.4 Monitoring criteria and relinquishment parameters

The following monitoring criteria could be used to define achievement of rehabilitation success. Parameters for setting associated relinquishment criteria are also provided.

<table>
<tr><th></th><th></th><th>Relinquishment parameters</th></tr>
<tr><td>Monitoring Criterion1</td><td>• Post-mining soil survey undertaken to determine replaced soils amelioration needs.</td><td rowspan="5">• Soil physics based on, at least, predefined:
– Rock content;
– Soil texture;
– Soil aggregation;
– Water holding capacity;
– Bulk density; and
– Available rooting depth.

• Soil fertility based on, at least, predefined:
– pH (KCl);
– Salinity (as electrical conductivity in mS/cm or resistance in Ω;
– Fertility: P as Bray 1 & K;
– Organic carbon (Walkley Black);
– Major cations: Ca, Mg & Na; and
– Cation exchange capacity (CEC).</td></tr>
<tr><td>Monitoring Criterion 2</td><td>• Replaced soils have been physically ripped and disced to alleviate compaction and improve soil friability for root penetration.</td></tr>
<tr><td>Monitoring Criterion 3</td><td>• Physical soil properties (water infiltration, crusting, bulk densities, etc.) are within range of a predefined functionality (yield and productivity) of the selected vegetation.</td></tr>
<tr><td>Monitoring Criterion 4</td><td>• Chemical soil properties (pH, salinity, nutrients, trace elements) of cover soils are within a predefined range for the selected vegetation root development and growth.</td></tr>
<tr><td>Monitoring Criterion 5</td><td>• Biological soil properties (organic matter status, nutrient cycling, microbial biomass, invertebrates) of cover soils are within predefined functionality (yield and productivity) of the selected vegetation.</td></tr>
</table>

10. REVEGETATION

10.1 Context

There has been a tendency to view revegetation as part of physical stabilisation activities. Accordingly, in certain sectors of the industry revegetation standards employ “seed cocktails” – principally grasses, which establish rapidly and provide excellent protection against surface erosion. While this will be the desired end-product in lands designed for ultimate arable or grazing land uses, it may not be the best approach in areas where biodiversity objectives have higher priority. The revegetation objectives should be set to meet the site’s agreed post-mining land uses. These can take the form of rehabilitation to rangeland (most of Mpumalanga Highveld), or to indigenous grassland, wetland, intensive agricultural crops, or reforestation.

Vegetation has a primary functional role. A good vegetation cover limits soil erosion and associated soil loss; improves soil stability and structure over time; and reduces infiltration to underlying spoils. Root systems are of particular importance for both structural stability of replaced soils, as well as plant water use efficiency. Individual species may vary in their rooting behaviour, but soil type and quality (chemical and physical properties), as well as the groundwater regime, strongly influence root development. Roots in well-drained soils go deeper and exploit a much larger volume of soil than those in heavy hydromorphic soils (where waterlogging can restrict root survival due to anaerobic conditions), while a high groundwater table or a layer of densely compacted soil will force roots to spread laterally. The majority of roots are usually found within the upper 300 – 400 mm of the soil profile in herbaceous vegetation, and up to 3 m in vegetation dominated by trees and shrubs[37].

A good re-established vegetation cover also provides a vital role in controlling the germination and growth of alien invasive species, which continue to be a major problem in many mining areas.

Biologically, vegetation forms the basis of habitat from which dynamic multi-species ecological systems can develop and flourish. From a rehabilitation perspective, development of a natural succession from pioneer to climax communities through a number of progressive stages becomes critical for long-term system resilience. Succession implies a change in soil characteristics as well as species composition. These changes generally result in a reduction in soil bulk density and an increase in permeability. Given sufficient time, the progress of succession starts from bare ground to herbs and grasses, shrubs and, in some ecosystems, then tree cover[37]. On the Mpumalanga Highveld, which is a biome exposed to regular fires (via lightning), grasses remain as the climax species dominating this landscape.

Aesthetically, vegetation also has an important role in shaping perceptions around the success of rehabilitation.

[37] Coppin, N.J. & Richards, I.G. (2007): Use of Vegetation in Civil Engineering. ISBN 0-86017-711-4. London, UK.

Once established and well-managed (suitable soil replacement, species selection, ongoing amelioration and invasive species control), vegetation is a self-replenishing and minimum maintenance intervention that can sustain rehabilitating landscapes over time.

Thick, well-established vegetation cover - improving water and nutrient use efficiency, and limiting erosion risk

Native species for biodiversity-driven rehabilitation

10.2 Rehabilitation objectives

The following rehabilitation objectives should guide re-vegetation:

Objective 1	To reduce soil loss to a minimum.
Objective 2	To optimise the efficient use of water within the rehabilitated landscape.
Objective 3	To enable long-term functionality of the predefined land-use/s.
Objective 4	To form the building-blocks for a resilient ecological system, so that successional processes lead to the predefined vegetation complex.

10.3 Actions

The following actions should be implemented to ensure appropriate revegetation:

Action 1	• Identify species well-adapted to local climatic conditions, and that can provide functional use as part of the predefined post-mining land use/s.
Action 2	• Plan to sow / plant when seasonal conditions are most likely to ensure successful germination and growth.
Action 3	• Apply planting methods best suited for the surface landform profile and species selected.
Action 4	• Apply appropriate sowing/planting rates.
Action 5	• Apply ongoing maintenance on establishing vegetation.
Action 6	• Control invasive (alien) species.
Action 7	• Implement biodiversity off-sets as a last resort, only if on-site rehabilitation is not possible.

10.1.1 Identify species that are well-adapted to local seasonal conditions, and can provide functional use as part of the predefined post-mining land use/s

The revegetation objectives should be set to meet the post-mining land uses that have been agreed for the site. These could be the re-establishment of the native vegetation, erosion control for the protection of water resources, establishment of high-quality grazing or the preparation of lands for arable use.

Species selected for rehabilitation establishment should provide protection from erosion and meet the biodiversity objectives. However, the primary objective of revegetation is the reduction of soil loss to a minimum. Rehabilitated soils in most cases are inferior to the natural profile (due to compaction, mixing of surface with subsoil horizons, etc). As a result, they are less satisfactory as a plant growth medium, having lower organic matter content, reduced chemical fertility, degraded physical condition and depleted microbial populations. Accordingly, even where crop production is the ultimate objective, it is essential to keep the land under permanent vegetative cover for a number of years to re-establish organic carbon status and the natural nutrient recycling processes.

The following criteria are considered critical for the selection of appropriate species for rehabilitation[38]:

[38] De Villiers, J. (1981): Guidelines for the Rehabilitation of Land Disturbed by Coal Mining in South Africa.

- Use species that are well adapted to local climatic conditions and post-mining land use needs.
- Select species that are tolerant to the site's specific adverse soil conditions (e.g. acidity, compaction, metal toxicity, levels of drought).
- Ensure preferred species are dominant in the revegetated pasture (e.g. for grazing, use pasture grasses that should produce the desired quantities of above ground biomass, from prolific root systems).
- Ensure that perennial species form the basis of the revegetation program.
- Where possible, include an annual species – such as rye grass or teff, as a 'nurse crop' to quickly bind soils until perennial species have established in the second or third season.
- Ensure that at least one species used provides a rapid and dense ground cover during the establishment season.
- Ensure that good quality planting material or seed is readily available.
- Incorporate local experience regarding the establishment and maintenance of the species selected.
- Select species that have a low maintenance requirements, or with financial returns that exceed the production cost. As areas of rehabilitation expand, maintenance costs increase. In general, mining companies do not readily initiate farming enterprises on rehabilitated land, usually because of safety concerns, lack of farming knowledge and experience, and lack of accessibility to rehabilitated land within the active mining areas, etc. As a consequence, mining companies should rather focus on the modification of species composition on rehabilitated land to develop stable, low-maintenance pastures/ecosystems. This, however, should not be allowed to decrease productivity (yields), in the event that the land, post-mining, is intended to revert to arable cropping.

APPENDIX

Appendix K:
Considerations for vegetation selection
(MinCoSA, 2007)

There has been significant research and field trials around alternative post-mining land uses. In many cases, these are directly related to the type of vegetation planted and its use. This encourages consideration of alternative revegetation objectives, diverging from the traditional approach of establishing multi-species pasture crops. The following could be considered:

- Native species revegetation - planting species of local provenance that are suited to local conditions, with lower nutrient needs and lower overall maintenance requirements.
- Food crop establishment - successful establishment of oats, soy, maize, nuts and fruit trees has been proven successful over recent years. However, irrigation is generally required to achieve economically viable yields.

- Energy crop establishment - introducing high-biomass species requires very high inputs. However, the lucrative nature of the outputs justifies the additional and focussed maintenance required.
- Afforestation - utilising the superior phyto-evaporative transpiration potential of woody species to intercept shallow groundwater pollution plumes; or even use of the timber (or bark for tannins) as part of an economic value chain within the post-mining landscape.

Planting of bioenergy crops as a lucrative alternative post-mining land use

Afforestation: potential to use woody species for evapo-transpirative management of shallow groundwater seepage

It is noted that there is a significant opportunity for mines to hand rehabilitation over to farmers to graze as early as possible (once fertiliser levels start to stabilise) – where this does not interfere with mining. Livestock on rehabilitated land can greatly enhance nutrient recycling.

Also, the opportunity for native species introduction is best suited for wilderness areas as these areas can never be intensively grazed (nor cropped). These areas should be used for biodiversity enhancement and, provided this can be incorporated into the rehabilitation design, these areas can act as corridors between naturally diverse areas. However, it is usually more expensive to establish native species (if the soil seed bank is poor) because native seed - which is usually hard to come by, must be purchased from specialist suppliers or harvested locally – which is time consuming and costly. In addition, the germination potential from native species is generally lower and likely to be more variable depending on when seed is harvested and what the growing season was like (good or poor rainfall, etc).

10.1.2 Plan to sow / plant when climatic conditions are most likely to ensure successful germination and growth

Water availability greatly improves vegetation establishment and rehabilitation success. However, because irrigation of large tracks of rehabilitated land can be costly and impractical for vegetation establishment, seeding and planting is generally done so as to coincide with the wet season, which provides ideal germination and growth conditions for the establishing pastures.

Aligned to the above, seeding and planting is most successful when done at or immediately after the first rains in spring, and into freshly prepared, fine-tilled seedbeds (where soils are not prone to crusting).

To stimulate germination, water retention in the seed zone is essential and can be aided by the application of light vegetation mulches and/or scattering of light woody debris. Woody debris and grass mulch have the added benefits in that they increase organic carbon in the soils as they decompose and create micro-habitats for invertebrate and faunal colonisation. However, the application of woody debris and mulches can be labour intensive and costly, and care must be taken not to use species that could increase the risk of introduction of invasive species (such as wattle in the Mpumalanga Province).

Woody debris for nutrient recycling, micro-habitat creation and soil moisture retention

Hygroscopic gels, especially in low rainfall areas, can be incorporated into the seed mixes to enhance the water-holding capacity of the soils. These gels are a cross-linked polymer, comprised solely of sodium polyacrylate, that is not toxic to humans, animals or plants, and which only absorbs water or aqueous solutions. Hygroscopic gels are usually mixed with a growth medium or soil in the immediate vicinity of plant roots, thereby helping to reduce the risk of plant mortality through drought, when there is insufficient rainfall or no artificial irrigation. Unless stated by the manufacturer as containing one or more elements that are essential for plant growth, hygroscopic gels are not fertilisers[39].

Care should be applied when using these gels with seedlings (trees or grass plugs) – for example, if the gel desiccates, then the shrinking effect can 'break' the roots causing stunted plants that then rarely recovered properly[40].

[39] Granger, J.E. (2015): Rehabilitation and conservation management plan for the proposed Avoca South Industrial and Business Estate, Durban North, Kwazulu-Natal. Specialist report prepared by J.E. Granger (PhD), Themtek Environmental Consulting CC for GCS Water & Environmental Consultants. April 2015.
[40] *Pers. Comm.* Dr Mark Aken (June 2019)

10.1.3 Apply planting methods best suited for the surface landform profile and species selected

A range of methods is used, depending on revegetation goals. The more common methods for revegetation (following amelioration and land preparation) are seed drilling, seed broadcasting, no-till planting, hand plant translocations, sodding, sprigging, hydroseeding, gel planting, aerial seeding, or passive revegetation through relocating seedbank-rich topsoil directly.

Seeding with commercially available seed

For the majority of South African situations, where the re-establishment of the full range of native species is not the prime objective, seeding is the commonly used method.

Appropriate commercially available seed mixes have been developed for various climatic and soil combinations and these have proved effective in generating a rapid erosion controlling cover that is sustainable under normal management conditions.

Most commercially available seed mixes generally have a good initial response within the first few seasons, where after one or more species normally dominate. This can result in a monoculture pasture which, if this is not the desired end product, will require unnecessary re-seeding. In addition, commercial grass species (improved pastures species) that have been bred for high production, typically require high levels of fertiliser input in order to maintain adequate production and cover. Commercially available seed is relatively cheap and easily accessible and, if managed properly, can produce sustainable pastures supporting a predefined land use on a rehabilitated landscape.

Seeding with locally collected (native) seed

A pristine Highveld grassland has more than 30 species of grass and twice as many forb species. Hence, locally collected (native) seed will be fully adapted to the local climate and soil conditions, thus improving chances of germination and establishment success.

Many of the indigenous species (for example, *Themeda triandra*) need treatment (heat, smoke and scarification) to initiate germination.

Harvesting of locally collected native species for biodiversity-focused rehabilitation

Naturally harvested seed will only be available once a year, so this will also need to be accounted for in the site's planning. Planning for collection should begin at least 2 years prior to establishment with native seed to ensure that enough seed can be sourced.

It is recommended that the seed of native grass species be seeded in gel mixtures. In this case, seeding is best done using a gel planter when seeding directly into the soil on flat areas or using a hydroseeder to spray seed onto the surface of rehabilitated areas (typically steep slopes). The gels used when seeding native species are either a natural product (guar gum or psyllium) or a synthetic anionic polyacrylamide. While the gels do assist with water retention of water, the main objective of using these gels with native seeding is to make it easier to manage/apply the seed. (This contrasts with the planting of rooted seedlings/saplings/plug, as mentioned above, where water retention is the main requirement for seedling/sapling success).

Direct soil placement

Less frequently, the rehabilitation objective is the restoration of previous species composition. In this case, direct topsoil replacement is a valuable technique that has been practised, for example, at sand mining operations in the Western Cape. While a significant proportion of the original plant species can be established in this way, there remain some “recalcitrant” species that require specialised treatment. In windy areas, such as the Western Cape, windbreaks are required to retain replaced soil.

Direct replacement of soil with windbreaks to prevent wind erosion

Natural re-establishment

Methods of spreading seed

The spreading or sowing of seed is usually done by hand, or by using a seed drill, tractor-mounted seed spreader, gel planter, hydroseeder, or aerial application. Seed can also be introduced by thatching or mulching prepared areas with gravid (seed bearing) grass material, which is a particularly effective method for reintroducing *Themeda* and *Hyparrhenia* into rehabilitated pastures.

Planting of seedling plugs

Not frequently used in South Africa, the use of plug seedlings for establishing ‘islands’ of indigenous species has been done experimentally, again to stimulate the reintroduction of *Themeda* and other native species into rehabilitated areas in the Mpumalanga coalfields.

Planting of vegetative material

Planting of vegetative sprigs or plants of indigenous species can, in many instances, offer an alternative to the constraints of indigenous seed only being available once a year after grasses have flowered. The planting of runners, sods and sprigs has been used for the establishment of kikuyu and star grass pastures, as well as for establishing stabilising contour rows of *Vetiver* of steep slopes.

All vegetative material requires hand-planting in South Africa, as sprig planters are currently not commercially available.

Stockpiles that will remain in location for more than one growing season, and that have not revegetated naturally, should be revegetated to avoid erosion losses. To preserve the looseness of the stockpile (where this has been achieved by correct stripping and construction of the stockpile), fertilisation and seeding should be done by hand, by hydroseeding or aerially to prevent wheel pressure compaction.

10.1.4 Apply appropriate sowing/planting rates

The extent of vegetation establishment on rehabilitated areas (measured as plant density, basal cover, canopy cover, biomass, etc.) initially depends on the weight of seed applied, and or the density/spacing of handplants, etc.

For vegetative sod material, the density of handplants or row spacing of contour strips is based on soil erodibility, slope length and angle.

For seeding, it would be assumed that under most circumstances the soil surface is (or will be) stable during the seed germination and establishment phase. Seeding rate is generally selected to prove the optimal plant density to stabilise the soils (initially) and then to meet economic output requirements. For example, you could get a higher economic output from a less dense (lower basal cover) grass sward that is well fertilised (high above ground biomass) than a denser pasture that is not fertilized.

10.1.5 Apply ongoing maintenance on establishing vegetation

Once established, vegetation requires regular maintenance. When the growth medium comprises low fertility soils or overburden, vegetation maintenance requires regular application of plant nutrients, either in the form of inorganic fertilisers or manure, until the natural fertility cycle has been restored.

This may take many years to achieve and has not been the subject of research locally. Empirically, the norm has been to continue fertilising annually for at least three years, and then to apply fertiliser every three years, as required and informed by soil analyses. In some cases, however, successful and sustainable vegetation cover has been achieved through the application of a single pre-planting application of fertiliser at the appropriate rate.

Grasses require some form of use. If not regularly defoliated they become moribund and die off, thus exposing the soil to erosion and providing open spaces for invasion by weeds. Defoliation is normally done by grazing or by mowing. In some instances, controlled burning has been used. However, burning is the least desirable option as the carbohydrate energy in dried grass is largely converted to heat and CO_2 (a greenhouse gas) during burning, where it should rather be used to provide carbohydrate feed for livestock production. Some ecosystems – such as the Mpumalanga Highveld grassland biome, require fire for their propagation and perpetuation, and burning at strictly defined intervals may be unavoidable. Mowing, and use of the removed vegetation as hay, requires less supervision than grazing, but the disadvantage is that large quantities of plant nutrients, in particular potassium, are removed in the hay. Mowing will require the application of larger dressings of fertiliser to maintain the soil fertility at desired levels.

Grazing, in contrast, ensures nutrient recycling and organic matter return to the soil, but is more difficult to manage. Rehabilitated land may be leased for grazing, but close supervision is required to prevent overgrazing. Some mines have their own cattle herds to graze rehabilitated pastures, an option that requires significant managerial input and oversight. In both cases, livestock on rehabilitated land must be carefully managed to ensure that early grazing does not impede vegetation establishment. This may involve animal exclusion for at least two years, or focused camp rotation. Temporary fencing may be necessary to minimise the impacts of wildlife and livestock grazing.

Mature rehabilitated land with native species (Hyparrhenia) beginning to dominate the vegetative cover

Inclusion of rotational cover crops, such as legumes, cabbages, radishes, etc. as part of the revegetation plan can greatly improve the organic material content of the replaced soil. This organic matter improves the water holding capacity of the soil and provides food for beneficial micro-organisms that are key to re-establishing the soil nutrient cycling processes, that are essential for sustainable plant growth.

10.1.6 Control invasive alien species

The most effective, economical, and ecologically sound approach to managing invasive (alien) plants[41] – often categorised as 'weeds', is to prevent their invasion in the first place. Once invasive species have infested a rehabilitated site, management is expensive and eradication is very difficult, if not impossible. Limited resources could be spent more efficiently on proactive weed management that controls existing weed infestations, and also focuses strongly on prevention, or early detection, of new invasions.

41 Clark, J. (2003). Invasive Plant Prevention Guidelines. www.weedcentre.org

In South Africa, management of invasive species is legislated in terms of NEMBA[42], where:

- Category 1a species are considered emerging invasive species that require immediate compulsory control and where eradication is a possibility;
- Category 1b species are established invasive species that include the most widespread and troublesome of the species, which require control and where landowners must comply with invasive species management programs;
- Category 2 species are those commercial plantation species that require permits for cultivation and which require control outside of the specified areas allowed for cultivation; and
- Category 3 species are subject to exemption but have the potential to become invasive and therefore must be controlled. They are prohibited in riparian areas[42].

Species such as black wattle (*Acacia mearnsii*), pink tamarisk (*Tamarix ramosissima*), pampas grass (*Cortaderia selloana*), wild tomato (*Solanum sisymbrifolium*), cosmos (*Bidens formosa*), common blackjack (*Bidens pilosa*), khakibos (*Tagetes minuta*), wild verbena (*Verbena bonariensis*) and the grey poplar (*Populus canescens*) are widespread (and difficult to manage) invasive species on South African coal mines in the Mpumalanga Province.

The following can be used as a guide developing a weed management plan[43]:

- Identify what weeds are present on the mine site, documenting those in active mining areas, in areas already rehabilitated, as well as in areas within the Mining Rights that are not disturbed by mining activities. Often there will be multiple weed species to deal with, so it is important to assess the weeds and their likely level of impact to prioritise resource allocation. Some weeds may not warrant control in the short-term, while others may require urgent attention.
- Map the location and extent of weeds on an aerial map or a detailed site map. This will help to prioritise the different areas on the site needing weed control. Also mark significant features such as infrastructure, roads, boundaries, areas of remnant vegetation and waterways - these could either be affected by the invasive species' growth or facilitate further infestation.
- Understand the lifecycle of the key weed species. When does the weed set seed? How is the seed spread? Is it an annual or perennial? How does it respond to frost? Does it prefer full sun or shade? Gaining a better understanding of the target weed and its lifecycle means that you can exploit its weaknesses, reduce its potential to produce further seeds and control it at the most effective time.
- Prioritise management. Is there a legal requirement to control the species? What is the level of threat to rehabilitated areas, native species and ecosystems? How is it affecting the structure and composition

42 Department of Environmental Affairs (2014). National Environmental Management Biodiversity Act, No. 10 of 2004. Regulation No. 589 – Alien and Invasive Species Regulation. South Africa

43 Australian Land for Wildlife. Undated. Developing a Weed Management Plan.

of the area that it is invading? Is it affecting infrastructure such as dams or fences? How fast is it spreading? What was its extent last year? Five years ago?

Once a good understanding has been developed of the site's invasive species, implement the following:

- Physically remove all identified alien invasive species seedlings from the soil by manually pulling them out with as much as possible of their root systems still intact.
- Physically remove trees by cutting or kill trees by ringbarking. Apply a chemical (herbicide) treatment on stumps and exposed bark to reduce the risk of future coppicing. Re-application of herbicide will be required to control any coppice growth and newly germinated seedlings as they emerge.
- Use chemical control methods including selective/non-selective, contact/systemic herbicides that are registered for use on the target weed species, and in accordance with the directions for the use of such herbicide. When controlling broadleaf invasive weeds in rehabilitated pastures, be sure to use a selective broadleaf herbicide so as not to kill the surrounding grass species.
- Avoid moving livestock from weed-infested sites to weed-free pasture.

10.1.7 Implement biodiversity off-sets as a last resort, only if on-site rehabilitation is not possible

In some circumstances, when biodiversity objectives are very difficult or impossible to achieve on the mine site, the objective of zero net loss of biodiversity on a regional or local basis can still be attained by the use of offsets. For the off-set to be valid, an off-mine site is selected for rehabilitation or exclusion from exploitation in order to compensate for the losses of the particular ecotype incurred at the mine-site. This is a complex subject, currently beset by practical pitfalls, but is a possible solution to some of the more difficult biodiversity challenges that are faced by mines.

Where possible, potential sites for restoration of biodiversity on the Mining Right should be sought, both to reduce the total area to be off-set elsewhere, and to better secure the off-set in the long-term.

ADDITIONAL RESOURCE

Mining & Biodiversity Guideline: Mainstreaming Biodiversity into the Mining Sector (DEA/SANBI, 2013)

10.4 Monitoring criteria and relinquishment parameters

The following monitoring criteria could be used to define achievement of rehabilitation success. Parameters for setting associated relinquishment criteria are also provided.

<table>
<tr><th></th><th></th><th>Relinquishment parameters</th></tr>
<tr><td>Monitoring Criterion1</td><td>Species have been selected based on their suitability and adaptability for changing local climatic conditions.</td><td rowspan="5">Vegetation cover has at least 15% basal cover - one-third of which is provided by perennial species.
Species richness (no. & type per ha) is at least 80% of that recorded at the analogue site or predefined criteria, with not more than 10 percent of the annual assessment plots failing to record this level of diversity.
Of the perennial species, one has a creeping habit.</td></tr>
<tr><td>Monitoring Criterion 2</td><td>Application methods are applicable to species used for revegetation (hand seeding, hydroseeding, etc.).</td></tr>
<tr><td>Monitoring Criterion 3</td><td>Achievement of predefined vegetation type, density and biodiversity (if this is a rehabilitation objective).
Achievement of predefined basal cover.</td></tr>
<tr><td>Monitoring Criterion 4</td><td>Species are capable of setting viable seed, flowering or otherwise reproducing (with evidence of a second generation of shrub and/or tree species' establishing in landscapes where these are required by the predefined land use/s).</td></tr>
<tr><td>Monitoring Criterion 5</td><td>Evidence that nutrient cycling is occurring, and that the presence of leaf litter is assisting in limiting erosion of the underlying soil.</td></tr>
<tr><td>Monitoring Criterion 6</td><td>For agricultural-driven rehabilitation targets, achievement of predefined pasture and crop productivity (yield).</td><td>Stocking rates (LSU/ha) do not exceed calculated stocking rates based on pasture productivity and pasture quality assessment.</td></tr>
<tr><td>Monitoring Criterion 7</td><td>Invasive species (weeds) are being managed and controlled and eradicated where required.</td><td>Ongoing monitoring shows that:
Target species persist;
Undesirable species that affect the intended land use do not dominate (e.g. Increaser I & II species do not replace higher value species).
Control measures have effectively eradicated invasive species or, for species with long-lived seed, annual maintenance measures are preventing re-infestation.
A Post-Mining Management Plan is in place, indicating ongoing management and care-and-maintenance requirements of established vegetation and land uses.</td></tr>
</table>

11. REMOVAL OR RE-USE OF SURFACE INFRASTRUCTURE

11.1 Context

Once mining has been completed, the processing facilities, accommodation and administration, mining, transport and storage facilities are usually surplus to the requirements of the post-mining land user. In some circumstances, certain portions of the existing infrastructure can be gainfully used after closure (for example, offices, workshops, etc.) and these structures need to be identified and protected.

Great care must be taken in determining which structures should be left for the next land user as, frequently, the future land user is over optimistic in estimating the potential of infrastructure to support the post-mining land use. Consequently, structures handed over in good faith become derelict and unstable, and present a health and safety hazard. Although the handover of such structures may be legally sound, the failure of infrastructure that has been handed over will always be associated with the initial mining company, as a reputational risk.

After identifying the structures that can be gainfully and sustainably used after closure, the remaining infrastructure should be removed so that the land can be converted to its final use. Infrastructure removal is a dangerous activity and detailed attention must be paid to managing safety risks.

Contaminated footprint areas that require clean-up and remediation prior to shaping and revegetation as part of the site-wide landform design

Often significant contamination on- and around access- and haul roads and rail lines that require dedicated clean-up prior to rehabilitation or re-use

11.2 Rehabilitation objectives

The following rehabilitation objectives should guide beneficial re-use of surface infrastructure, where appropriate:

Objective 1	To decommission, decontaminate (if necessary), dismantle and remove for safe disposal all identified surface infrastructure that has no beneficial post-mining re-use potential.
Objective 2	Following removal of unwanted infrastructure, to rehabilitate cleared footprint areas.
Objective 3	To stabilise and re-purpose remaining surface infrastructure that has a beneficial post-mining re-use potential.
Objective 4	To identify public-private partnerships and/or new owners for the ongoing, long-term management and ownership of remaining surface infrastructure.
Objective 5	To put in place formal agreements for the 'new owners' for the management and maintenance of remaining infrastructure.

11.3 Actions

The following actions should be implemented to ensure optimal beneficial re-use of surface infrastructure:

Action 1	• Compile a Surface Infrastructure Assets Register that clearly delineates surface infrastructure items that may have beneficial re-use potential for future land users, or need to be decommissioned, demolished and removed, and have salvage value (on-site or off-site).
Action 2	• Prior to re-use, removal or demolition, all hazardous and/or coal-contaminated materials and areas must be made safe and be cleaned up and/or be decontaminated.
Action 3	• Ensure that any infrastructure remaining as part of the rehabilitated landscape is safe and stable, according to professionally engineered designs.
Action 4	• Remove structures identified for off-site re-use, recycling or demolition.
Action 5	• Rehabilitate areas where infrastructure has been removed as part of the site-wide surface landform and profile design.
Action 6	• Compile formal agreements for hand-over and long-term management of remaining infrastructure.

11.3.1 Identify infrastructure items that may have beneficial re-use potential to future land users, or can be salvaged (on-site or off-site) (Surface Infrastructure Asset Register)

Engage with stakeholder who could be the post-mining land users, as well as the Authorities, to assess all structures and to determine which items can be left for beneficial re-use as part of the predefined post-mining land use/s which materials can be salvaged (recycled), and those with infrastructure that will need to be demolished. This should result in a Surface Infrastructure Asset Register that clearly defines at least the location and specifications of the infrastructure, its identified post-mining use, ownership and ongoing maintenance requirements. It should also identify its future physical safety for use, potential for secondary environmental impacts and the associated cost of retrofitting the specific mining assets for future use.

(Where potential post-mining uses of mining infrastructure are identified up-front, some of the associated costs may already be built-in with the initial design of the infrastructure. This may partially eliminate costs at a later stage, when the mine is already devoting large amounts of money in other areas of closure-related work. If future land uses of mine infrastructure are identified during mine planning, the potential to develop these after mine closure can be secured through appropriate and consultative planning).

Identification of reusable surface infrastructure is a difficult activity, particularly when the mine site lies within a farming community or is adjacent to an urban community, where many buildings can be seen as having value for storage after mine closure, or as workshops that will be of value for maintaining farm machinery. In some cases, where significant amounts of accommodation and office space are available, it may be possible to establish an enterprise hub or accommodation center.

However, South Africa has many examples of derelict mine infrastructure, where the controlling mining company handed the infrastructure over to the succeeding land users/owners in good faith – but the ensuing enterprise was not a success. It is essential, then, that the viability of any project, which will require the handover of mine infrastructure, be carefully researched before the mining company agrees to the handover to the next land users.

This should include adequate and appropriate legal input.

Frequently, retention of services such as roads, electricity supply, water supply, water treatment facilities (sewage plants) is requested. Although this infrastructure may have a beneficial re-use potential in the post-mining landscape, the ability of the new landowner/s to manage and maintain this infrastructure has, over the past years, proven to be inadequate. It is pointless, for instance, to leave a mine haul road as access to a small farming location as its maintenance cost will far outweigh the benefit. The need to fix derelict infrastructure then falls back to the mining house who may not have made the financial provision to manage the long-term liability. In each case, the probable future requirements of the ultimate land users and their ability to maintain the various infrastructure should be assessed.

Likewise, retained infrastructure for use by local communities (such as housing, sewage management, electricity connections, etc.), may incur ongoing costs that cannot be afforded by the communities. For example, sewage plants designed to cope with thousands of people will be overly expensive to maintain if only catering for a few hundred people. This places additional strain on local municipalities who will need to make-up the shortfall in rates and taxes – ongoing costs cannot then be met, and infrastructure falls into disrepair. Whatever infrastructure is handed over to subsequent land users must be correctly sized and financially viable to maintain.

The remaining infrastructure should be assessed for its suitability for re-use/recycling. Items such as cladding, roofing, electrical components, equipment, should be removed from the site prior to demolition occurring.

Many mine-related buildings, mainly those not directly used for processing (workshops, administration, etc.), can be re-used as part of the post-mining land use/s

While it would generally be considered that asset transfer would be a low-cost option, it is likely that not all assets will be fit-for-purpose and some expenditure will be required to either renovate or refurbish the asset prior to transfer. In this regard, the possibility of future mining/re-processing opportunities on-site, and within the greater region, where the possible extended use of existing infrastructure could be a benefit, must also be considered.

11.1.1 Prior to re-use, removal or demolition, all hazardous and/or coal-contaminated materials and areas must be made safe and be cleaned up and/or be decontaminated

All mine sites will have hazardous materials (pesticides, degreasers, hydraulic fluids, metallic sludges, etc.) in stores and stockpiles. The nature of these materials depends on the nature of the mining and processing that is being/was done. Many mines currently undergoing closure started before the present focus on environmental management. Consequently, the older mine sites will have a range of hazardous material dump locations, which may or may not have been identified and assessed. In addition to the hazardous materials, many of the areas on which surface infrastructure is located will have been contaminated by coal layers/veneers of various thickness. This is especially evident within coal stockpiling and processing areas, along haul- and access roads, conveyor routes, and along rail lines, sidings and other links or transfer points.

For all of these areas, a dedicated contaminated land assessment should be conducted to determine the presence and location of potentially hazardous and/or contaminated materials, wastes, and storage and workshop areas. The locations, quantities and sizes of these materials and areas will require specialised assessment and analysis to determine how best they should be decontaminated, remediated and/or disposed of. The clean-up volumes of contaminated wastes (e.g. coal veneers) will also need to be incorporated into the site's final landform design, for permitted disposal on the remaining mineral waste facility, prior to final rehabilitation. Hazardous materials must be disposed of in an authorised off-site hazardous waste disposal facility.

Contaminated land assessment identifying significant carbonaceous material contamination within the decommissioned processing plant's coal stockpiling areas

11.3.2 Ensure that any infrastructure remaining as part of the rehabilitated landscape is safe and stable, according to professionally engineered designs

Rendering all remaining infrastructure as safe and stable is a basic legal requirement for mine closure. For all retained infrastructure, sign-off of its physical stability need to be undertaken by a registered professional prior to change of ownership, especially where the infrastructure will be re-used for alternative purposes. Maintenance should be applied where required, aligned to legislative health-and-safety requirements.

All boreholes (except those retained for ongoing monitoring purposes) should also have been plugged or capped in terms of regulatory requirements.

11.3.3 Remove structures identified for off-site re-use, recycling or disposal

The infrastructure for which there will be no future on-site use should be demolished and recycled or re-used, where possible. Safety is a key issue in this activity, particularly where high structures are concerned, and care must be taken to push over all tall structures before final demolition occurs. In some cases, controlled explosion/implosion will be required. Concrete and brick structures are usually demolished using equipment fitted with hydraulic hammers.

Foundations should similarly be demolished, with the use of hydraulic hammers, and the rubble removed either to an adjacent rock dump, tailings deposit or shaft that has to be filled. Care must be taken to isolate any concrete structures with hazardous material contamination. This contamination may take the form of chemical toxicity. Such material will have to be deposited in registered hazardous waste disposal sites.

Items such as roof trusses and tiles, bricks, windows, lighting masts, etc. can be salvaged and re-used. This can either be undertaken by the demolition contractor, or by trained members of the community, where possible.

11.3.4 Rehabilitate removed infrastructure areas as part of the site-wide surface landform and profile design

Following removal of the infrastructure and contaminated materials, the infrastructure footprint areas can then be formally included in the remainder of the mine site rehabilitation process – where they can be reshaped, topsoiled and revegetated, aligned to the mine's site-wide surface landform and profile design.

In some cases, where infrastructure was developed and constructed before the need to cater for removal at closure was apparent, the foundations may be so massive that removal is impractical. In such situations, these structures should be integrated into the rehabilitated landscape by covering with a minimum of 1 m of cover material, prior to revegetation.

APPENDIX

Appendix 12:
Considerations for demolition of infrastructure
(MinCoSa, 2007)

11.3.5 Compile formal agreements for hand-over and long-term management of remaining infrastructure

Legal agreements need to be put in place for ongoing management of retained infrastructure by the new landowner/s. This will need to include and a Land Management Plan that provides ongoing care-and-maintenance requirements for the retained infrastructure (see Section 15.3 – Post-Mining Management Plan).

11.4 Monitoring criteria and relinquishment parameters

The following monitoring criteria could be used to define achievement of rehabilitation success. Parameters for setting associated relinquishment criteria are also provided, together with some examples (in brackets):

		Relinquishment parameters
Monitoring Criterion1	• Availability of a site-specific asset register identifying surface infrastructure that either needs to be removed or retained for future re-use.	• Availability of a detailed site-specific asset register that indicates status of infrastructure – what was demolished and removed, and what remains, etc. Includes ownership details of new owner/s.
Monitoring Criterion 2	• Surface infrastructure identified as having no beneficial post-mining re-use potential has been removed.	
Monitoring criterion 3	• Alignment of infrastructure footprint area rehabilitation with the mine's site-wide surface landform design.	• Contaminated land assessment (if needed) indicates how identified areas requiring clean-up have been rehabilitated (locations, volumes, disposal, surface profiling, re-vegetation, etc.). • Rehabilitated infrastructural footprint areas have been rehabilitation (shaped and revegetated) according to agreed-on site-wide surface landform design.
Monitoring Criterion 4	• For remaining surface infrastructure with a beneficial re-use potential, public-private partnerships and/or new owners have been identified; and management / ownership transfer agreements have been put in place for post-mining management.	• Legally approved transfer agreements in place for retained infrastructure. • Post-Mining Management Plan in place, indicating ongoing care-and-maintenance requirements of retained infrastructure.

SECTION C: MONITORING

12. PRINCIPLES OF REHABILITATION MONITORING

Effective rehabilitation outcomes depend both on the technical quality and quantity of the environmental data collected at a given site, and on the site's ability to react to the knowledge gained from that data. So, there is a need both to carefully monitor and evaluate the progress of the physical aspects of rehabilitation (such as soil stripping, overburden handling, landform development and soil replacement) during the operational phase as well as the progress with the re-establishment of the desired final land use functions and services.

The key objectives of rehabilitation monitoring are as follows:

- To verify that rehabilitation actions are being done exactly according to plan, that they are on time, and that their results are as expected;
- To ensure that timeous action can be taken to implement corrective action should applied rehabilitation actions have not resulted in the desired outcome; and
- To verify that the relinquishment criteria have been met so that the mine can apply for closure.

Monitoring mining rehabilitation tracks the progress from pre-disturbance to the attainment of the desired post-mining land use goals. Whether the post-mining land use is agricultural, conservation, urban development, recreational, or otherwise, a similar process needs to be followed. The general principles of rehabilitation monitoring are as follows:

- Monitoring should be initiated before the start of rehabilitation operations to establish the baseline values from which to track rehabilitation as the system recovers towards the pre-defined land capability and land use.
- Monitoring should track the progress of both physical site attributes and biological attributes by assessing both the actions being done (to ensure that the work has been done according to plan) and the outcomes of those actions (to ensure that the actions do result in the desired outcomes).
- Monitoring data on abiotic attributes must be used to calibrate outputs of risk-based prediction models. Ancillary data on surface water, dust fallout, etc., are useful in assessing whether overall rehabilitation objectives are being met by applied interventions and can indicate whether there are gaps in the planning or the implementation.
- The timescale of monitoring activities is complex and will be dictated by:
  - The extent of disturbance - the greater the degree of disturbance/destruction, generally the longer recovery will take and the longer the monitoring period;

- The extent of intervention - the more thorough and active the rehabilitation intervention, the quicker progress is generally shown and therefore the shorter the period to attaining relinquishment criteria;
- Post-rehabilitation maintenance and management - where no maintenance and/or mismanagement (grazing/burning) occur, development trajectories are generally retarded and therefore monitoring periods extend accordingly; and
- Climatic and biological influence - incident rainfall, heat units received and competition by weeds or pests all influence the recovery trajectory of rehabilitation.

For intensive land uses like crop production and forestry, similar principles apply but specific metrics will be required as the outputs are largely economic.

13. SETTING UP THE MONITORING PROGRAMME

13.1 The Monitoring Plan

The role of ongoing measurement and monitoring as part of rehabilitation planning should not be underestimated or assumed to be just another step in legislative and corporate compliance. It is essential that a detailed, relevant and comprehensive monitoring plan be develop with the aim to illustrate that the relinquishment criteria, as defined in the rehabilitation plan, are being met.

The following is a generic layout for a monitoring plan:

- Rehabilitation objectives;
- Key monitoring focus areas, per rehabilitation aspect;
- Site layout, indicating monitoring locations per rehabilitation aspect;
- Monitoring method / approach to be used;
- Monitoring frequency, duration and seasonality, if applicable;
- Relinquishment criteria to be achieved (target outcome for monitoring);
- Possible corrective action required if rehabilitation actions are not indicating a successful rehabilitation trajectory;
- Key team members responsible for monitoring activities, analysis and reporting; and
- Financial provisioning for monitoring (included as part of the site's annual rehabilitation costs).

EXAMPLE

Aspect	Monitoring		Relinquishment criteria	Corrective action
	Method	Frequency / duration		
Soil fertility	• Undertake representative soil sampling on rehabilitated areas (collect a composite soil sample of 20 subsamples for every 20ha land unit – collected in upper 150mm); • Submit soil samples to an accredited soil lab to conduct soil fertility analysis by determining the following, as a minimum: – pH (KCl); – Salinity (as electrical conductivity in mS/cm or resistance in Ω); – Fertility: P as Bray 1 & K; – Organic carbon (Walkley Black); – Major cations: Ca, Mg & Na; and – Cation exchange capacity (CEC)	Annually for the first 3 years, and every 3 years thereafter until targets are met.	• Rehabilitated soils are regarded as having adequate fertility when fertility analyses show: – pH is >pH5; – resistance is >300 Ω; – P is >20mg/kg; and – K is >100mg/kg	• Apply fertiliser and / or lime to any nutrient deficient rehab areas at application rates calculated to meet target fertility levels; and • Re-establish vegetation on bare patches where plant establishment failed and/or is underperforming

13.2 Monitoring focus areas

There is a need both to carefully monitor the progress of the physical actions of rehabilitation (soil stripping, overburden handling, landform development and soil replacement) during the operational phase, and the progress with the re-establishment of the desired final ecosystems. The list of items that should be monitored will vary from site to site and is usually based on the EMP commitments and relinquishment criteria that have been negotiated for the site.

Table 5 provides the main monitoring focus areas for the rehabilitation aspects discussed in Section B.

Table 5: Key monitoring focus areas for land rehabilitation

Rehabilitation aspect	Monitoring focus areas
Landform profiling	• Alignment of actual spoils and overburden placement compared to designed material movement and placement plan.
	• Alignment of actual reprofiled surface topography (slope profiles) compared to designed topography.
	• Actual areas (hectares) rehabilitated to different land capabilities compared to planned areas.
	• Stability and effectiveness of water management infrastructure under a range of rainfall events, over time.
	• Actual rate and effect of surface subsidence compared to predicted (modelled) rates.
	• Actual care-and-maintenance applied compared to planned requirements.
Soil stripping	• Availability of a site-specific soil stripping and handling plan, informed by a pre-stripping soil survey.
	• Total volume of soil available for stripping compared to the soil volumes actually stripped.
	• Percentage 'contamination' of stripped soils with other horizons.
	• Actual location of placement of stripped soils compared to planned locations, and volumes directly replaced (no stockpiling).
	• Time of the year during which stripping takes place.
	• Specific machinery used for stripping activities.
Soil stockpiling	• Materials balance including stockpile soil types, volumes and locations.
	• Dedicated construction designs exist for soil stockpiles.
	• Appropriate equipment used for stockpile construction
	• Soils of different types (upland and bottomland soils) stockpiled separately.
	• Stockpiles located in areas protected from contaminating materials and/or polluted water.
	• Stockpiles located in areas where they will not become waterlogged.

Rehabilitation aspect	Monitoring focus areas
	• Stockpiles are protected from upslope runoff by construction of bunds or trenches.
	• Stockpiled soils are revegetated, and soils are ameliorated as required whilst stockpiled.
Soil replacement	• Achievement of planned soil depth and slope.
	• Erosion rates are meeting predefined limits.
	• Degree of compaction of replaced soils, to inform the level of effort needed for ripping for compaction alleviation.
	• Achievement of planned landform-related rehabilitation objectives.
	• Use of correct equipment to place and spread soils.
Soil amelioration	• Post-mining soil survey undertaken to determine replaced soils amelioration needs.
	• Replaced soils have been physically ripped and disced to alleviate compaction and improve soil friability for root penetration.
	• Physical soil properties (water infiltration, crusting, bulk densities, etc.) are within range of a predefined functionality (yield and productivity) of the selected vegetation.
	• Chemical soil properties (pH, salinity, nutrients, trace elements) of cover soils are within a predefined range for the selected vegetation root development and growth.
	• Biological soil properties (organic matter status, nutrient cycling, microbial biomass, invertebrates) of cover soils are within predefined functionality (yield and productivity) of the selected vegetation.
Revegetation	• Species have been selected based on their suitability and adaptability for changing local climatic conditions.
	• Application methods are applicable to species used for revegetation (hand seeding, hydroseeding, etc.).
	• Achievement of predefined vegetation type, density and biodiversity (if this is a rehabilitation objective). • Achievement of predefined basal cover.
	• Species are capable of setting viable seed, flowering or otherwise reproducing (with evidence of a second generation of shrub and/or tree species' establishing in landscapes where these are required by the predefined land use/s).

Rehabilitation aspect	Monitoring focus areas
	• Evidence that nutrient cycling is occurring, and that the presence of leaf litter is assisting in limiting erosion of the underlying soil.
	• For agricultural-driven rehabilitation targets, achievement of predefined pasture and crop productivity (yield).
	• Invasive species (weeds) are being managed and controlled and eradicated where required.
Surface infrastructure	• Availability of a site-specific asset register identifying surface infrastructure that either needs to be removed or retained for future re-use.
	• Surface infrastructure identified as having no beneficial post-mining re-use potential has been removed.
	• Alignment of infrastructure footprint area rehabilitation with the mine's site-wide surface landform design.
	• For remaining surface infrastructure with a beneficial re-use potential, public-private partnerships and/or new owners have been identified; and management / ownership transfer agreements have been put in place for post-mining management.

The following section provides further detail on some of the key focus areas mentioned above.

13.2.1 Landform profiling

<u>Alignment of actual final topography to agreed planned landform</u>

Topography achieved, in relation to that actually planned, should be monitored regularly – the intervals between assessments will depend on the rate of pit development and reshaping. The key is to ensure that the final profile achieved is acceptable in terms of the surface water drainage requirements and of the post-mining land capability needs. To this end, sign-off of the reshaped area is required before topsoil is to be replaced.

Normally, assessment would be done by the survey department, with signoff by the rehabilitation specialist.

<u>Erosion</u>

Erosion status of the rehabilitated land should be monitored, and zones with excessive erosion should be identified for remedial action. Erosion can be quantified by insertion of marked stakes into the rehabilitated profile and recording the rate at which the stakes are uncovered. However, the norm is simply the recording of the existence of erosion in a particular location.

Measured erosion rates meet predefined limits (derived from in situ trials or calculated from the Universal Soil Loss Equation or a similar agreed method).

Surface water drainage systems and surface water quality

The functionality of the surface water drainage systems should be checked annually, preferably after the first major rains of the season, and then after any major storm. This is both to ensure that the drainage of the re-created profile matches the plan; and to permit early repair of drainage structures that are not functioning efficiently, before they break and cause significant erosion damage.

Water quality leaving the property (and at any other locations within the property specified by the site's water use licence conditions) should be monitored regularly. Samples taken should be analysed for particulate and soluble contaminants and for biological contamination.

Groundwater quality at agreed locations

Similarly, groundwater levels and quality should be measured at agreed locations in order to determine the impact of the mining operations on groundwater quality. The location of the monitoring positions should be set by a hydrogeologist in association with the regulatory authority. Monitoring locations should be down slope, hydrologically speaking, of the rehabilitated area.

Monitoring frequency, likewise, is dependent upon the requirements of the regulator. Usually, there will be a requirement for monthly monitoring for the first year or two after installation of the monitoring boreholes. Thereafter, provided the monitoring results indicate little or no change with time, monitoring frequency may be decreased to once per quarter, or, in rare cases, annually.

13.2.2 Soil stripping, stockpiling and replacement

Depth of topsoil stripped and replaced

Recovery and effective use of all available usable topsoil is essential. Regular reconciliation of volumes of topsoil stripped, stockpiled and returned to the reshaped landform is vital. Some companies have developed topsoil balances to keep track of soil resources. Assessment, on a regular basis, of the stripping process is required to ensure that the correct depth of stripping has been employed; that there is no mixing of suitable and unsuitable soil horizons; that the stripped materials are being replaced in their correct locations; and to the correct depth.

The materials balance should compare the volumes of soil stripped with the volumes replaced and stockpiled. Exact balance is not expected, due to losses in transport and compaction; however, losses in excess of 10% should be investigated immediately.

13.2.3 Soil amelioration

Chemical, physical and biological status of replaced soil

The depth of replaced soil should be assessed using a soil auger in a regular grid pattern. Standard spacing of auger holes is 100m by 100m, giving coverage of one hole per hectare. In some cases, sampling density should be increased. Augering should be done until spoil materials are intercepted. In most rehabilitated profiles, this interface is clearly distinguishable.

Confusing factors include rock introduced into the topsoil either naturally (the original soil material was stony) or as a result of deep ripping, which has brought rock into the overlying topsoil strata. Where auger results do not match expectation, several pits should be dug to find the explanation. Each auger hole should be georeferenced, and the results plotted. Several soil pits should be dug in the rehabilitated profile. These should penetrate at least 100 mm into the underlying spoils and at least one should be dug for each rehabilitated soil unit. Normally, one soil pit should be dug in each uniform area of rehabilitation. A maximum area of 100 hectares could be covered by a single pit if the rehabilitated area is very homogeneous, but normally the variability is such that a much denser distribution of soil pits is required to properly assess the nature of the rehabilitated profiles. Inspection of these holes will permit the identification of compact soil layers and the degree of disturbance of the soil/spoil interface – and of the plant rooting pattern, provided the holes are dug at least one season after initial plant establishment.

Soil fertility sampling should be done independently of the auger soil survey. While a bucket auger can be used for soil fertility assessment, specialised “bicycle handlebar” (beater) augers make the task simpler. For each field to be assessed, the areas should be split into logical land use units and rarely should these units be larger than 100 hectares. For each homogenous unit, at least 20 sub-samples should be taken in a v-shaped or zig- zag distribution across the unit and mixed and sub-sampled.

This should be done pre-establishment, so that immobile nutrients such as lime and phosphorus can be applied and incorporated deep into the plant rooting zone during the initial tillage process. Analysis of the rehabilitated paddocks should continue for a number of years, until the desired fertility status has been achieved.

Heavily compacted soil and spoil

Rooting in compact profiles is restricted to the loosened surface and to cracks in the sub-surface horizons

13.2.4 *Revegetation*

Vegetation basal cover

Basal cover is the measure of the proportion of ground, at root level, that is covered by vegetation and, more specifically, by the rooting portion of the cover plants. It can be measured by the line-transect method (where a rope or line some 50 - 100m long is drawn over an area and the length of rope vertically overlying living basal cover is measured).

Rooting portion of the cover plants at ground level, indicating good basal cover

Alternatively, a quadrat bridge can be used to establish random sampling positions and in excess of 2,000 points should be recorded.

The norm that can be expected will vary depending on climatic and soil conditions. However, for the Mpumalanga Coalfields, for instance. a target of 15% basal cover has been set for fully established (i.e. second season and beyond) vegetation.

Vegetation species diversity

Where the re-establishment of natural plant communities is the objective, success is recorded on the basis of both the cover of vegetation achieved and its composition.

The metric used is the proportion of pre-existing species that have become established in the rehabilitated profile.

Scientifically rigorous procedures are required. It is usual for the biodiversity surveys to be done by external experts. In order to establish the full range of plants that have become established, it is necessary to do both summer and winter samplings as plants are identified by their flowering parts and these develop at different seasons, depending on plant type.

Crop growth and yield (on sites rehabilitated to agricultural post-mining land uses)

Crop growth and yield, in relation to climatic conditions, should be recorded for all crops and improved pastures grown on rehabilitated land. This is to build up evidence of the relative “capability” of the new profile to support crops, in relation to the previous unmined condition. This is done by recording the numbers of grazing days, hay bales produced and their average weight, or by recording mass of grain or another crop produced per unit area.

Cattle grazing on rehabilitated pasture land

Management and control of alien invasives

Alien invasive species tend to thrive in disturbed areas (such as those that have been mined). They can cause a decline in biodiversity and the local extinction of indigenous species. They can also decrease the productivity of agricultural land and rangeland, increase agricultural input costs, reduce stream flow in rivers, submerged aquatic invaders can cause oxygen deficiencies in water[21].

Once invasive species have infested a rehabilitated site, management is expensive and eradication is very difficult, if not impossible. Limited resources could be spent more efficiently on proactive weed management that controls existing weed infestations but also focuses strongly on prevention or early detection of new invasions.

Proactive, ongoing management of invasives species is therefore critical to successful rehabilitation implementation.

Faunal recolonisation

Again, evaluation of faunal recolonisation requires expertise that is usually external. However, valuable information can be obtained by regular recording, by mine personnel, of the presence of mammals, reptiles, birds, frogs and invertebrates on the rehabilitated lands.

13.3 Predictive modelling to define monitoring requirements

Due to lack of reliable case studies or long-term site data, predictive modelling is often the preferred means of quantifying relative outcomes of rehabilitation projects, as well as defining monitoring criteria. It is particularly useful for comparing different scenarios for rehabilitation, such as levels of vegetation cover, soil cover types and thicknesses, slope angles, surface subsidence, stormwater and geohydrological impacts.

Predictive modelling uses past climatic data in association with data on soil/spoil physics, soil/spoil chemistry, vegetation cover, water attributes and landform parameters to predict future rates of change of parameters over time.

It is important to note that predictive modelling is generally aimed at parameters involving the surface horizons (upper spoils, subsoil, topsoil and vegetation) and not the deeper horizons. No matter how well modelled or designed a post-mining landform is, if discard/overburden replacement is poorly undertaken, surface failures remain a risk.

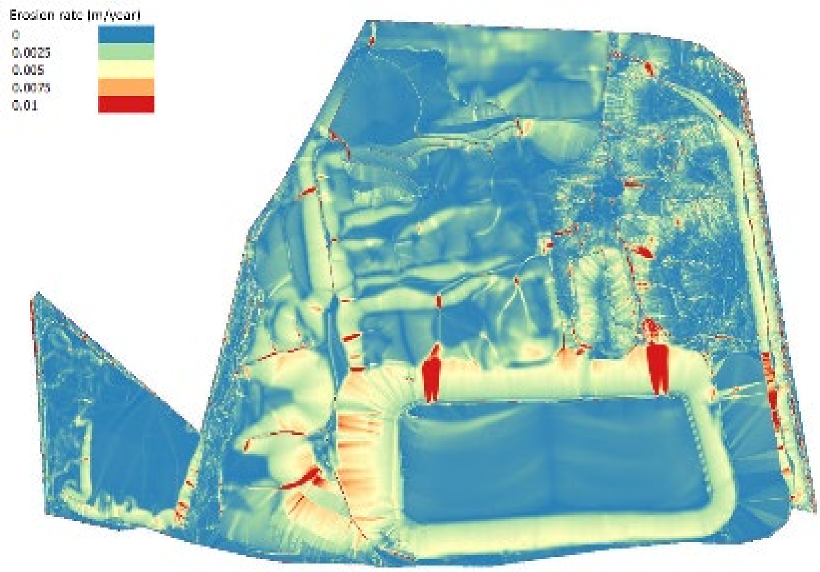
13.3.1 Reconstructed landform stability and ability to support the intended final land use

The reshaped topography must be such that it conforms to the requirements of the desired post-mining land use and of the post-closure water-balance requirements. Topography, soil thickness and other conditions (such as levels of compaction) must be such that they do not unnecessarily restrict the activities of the next land user. Key to this is the understanding of the long-term stability of the re-created landform. Will the surface soils applied withstand erosion? Will differential subsidence result in failure of drainage structures or restrict agricultural use of the final landform? The answers to such questions, which will quantify residual risk, will enable the development of methods of managing the residual risk associated with the re-created landform.

From a predictive modelling perspective, during landform design, pre-mining data on soil forms, bulking factors, depths, volumes and textures informs a site-specific soil management guideline. This would typically specify the stripping depths and volumes, as well as stockpile separation for different soil types and horizons per defined unit area. This data is used by landform designers to create representations of suitable post-mining landforms that minimise erosion and differential settlement, reduce stormwater management complexity and improve overall rehabilitation success and optimised costs.

Establishing erosion likelihood and predicting the rates of stochastic and long-term erosion at specific scenarios of slope geometry and vegetation cover informs maximum slope lengths, angles and shapes for specific soils in different rehabilitation areas.

The models can also predict where water is likely to pond and where ingress rates will be high, potentially leading to settlement or subsidence. Should these be encountered, then alterations to the landform design, soil placement or spoil consolidation are specified to avoid them.



Erosion modelling to determine erosion rates on the rehabilitated landscape over time

13.3.2 Surface and groundwater quality compliance with agreed conditions

It is essential that surface- and groundwater qualities leaving the property meet agreed-on relinquishment criteria, both at the time of closure and into the future. The requirement, then, is for detailed predictive modelling to have been done of potential future water impacts of the rehabilitated area and for detailed monitoring to have been done for an agreed period post-decommissioning. If the monitoring results align well to the predictive model, then the long-term residual and/or latent risk can be reasonably quantified

Surface water

For rehabilitation planning on active mine sites, a dedicated network of clean versus dirty water separation interventions is required to prevent clean runoff water from becoming contaminated, and from contaminated water affecting 'clean' land or water. Predictive modelling represents the impacts of peak-flow storm events to highlight the scope and extent of interventions required such as location of berms, depth and width of diversion channels and stormwater dams or pollution control dams. These will remain active until all areas are rehabilitated and designated as 'clean' areas, when it should be possible to remove almost all of the clean and dirty water separation infrastructure.

Decant is a significant risk that requires management as it can cause deterioration of surface water resources. Geochemical modelling of water qualities in relation to remediation scenarios is useful in selecting technologies/practises that will enable compliance to water use licence guidelines or gazetted Standards.

Coal discard dump toe seepage

Groundwater

Groundwater contamination is one of the main latent impacts preventing mine closures. Rainfall that enters rehabilitated areas will, if not intercepted by vegetation, evapotranspired or suspended within the soil cover matrix, seep into the underlying spoils where it becomes a vector for contaminant transport. Predictive modelling is used to estimate the rates of ingress into spoils and, in conjunction with geochemical modelling, can then define the volumes and concentrations of contaminants that will enter groundwater.

Geohydrological modelling then uses this information as input data, along with geological information, to identify the extent of groundwater contamination plumes (along with expected concentrations of elements of concern at different time intervals) and where decant will take place, and at what volumes and concentrations.

This modelling is also critical in understanding of the implications of the re- establishment of the water tables within the rehabilitated land; as the long-term availability of this water could be critical to the resilience of the established vegetation cover.

The water-related modelling will help develop a management plan for the likely quantities and qualities of water emanating from the site. This may include the provision of financial capital and operating costs, in perpetuity, for water management facilities.

13.3.3 Vegetative cover health, resilience and suitability for the desired post-mining land use

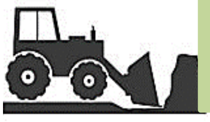
The vegetative cover health issue is not related to the status at a point in time but rather to the dynamics of the ecosystem that has been established. Are desirable species increasing with time, and undesirables decreasing? The level of control of alien invasive species should be at least as good as that found in neighbouring non-mined properties.

Detailed assessment of ecosystem composition and dynamics are required so that an assessment of the long-term stability can be made.

13.4 Frequency of monitoring

Implementation of monitoring keeps the rehabilitation on track – when things go wrong, the mine will know if this was due to the action being implemented incorrectly, if the action was incorrectly designed in the first place or if the action is unsuitable due to changing site conditions. The more frequently rehabilitation monitoring is undertaken, the sooner mine personnel will be aware of these possible challenges and be able to implement the required corrective action. This is invaluable for the efficient management of the entire rehabilitation process!

If the monitoring output does not feed back into the rehabilitation management system with a very rapid response, monitoring will be a waste of time! It will only tell you what went wrong or what went right.



THE FREQUENCY AND CONTINUAL NATURE OF MONITORING OF REHABILITATION ACTIONS IS CRITIAL TO THE SUCCESS OF SITE REHABILITATION.

13.5 Key team

Rehabilitation is not the sole responsibility of one team member of the site. Nor is it the responsibility of an external consultant. Instead, development of the rehabilitation plan and successful implementation of its actions is a team effort (Table 6):

Table 6: Mine team members responsible for site rehabilitation planning and implementation

Mine team member	Rehabilitation responsibility
Operations Manager	• Operational leadership to define and implement long-term operational sustainability, of which rehabilitation planning is an integral component.
	• Identification of rehabilitation-related risks, and decision-making of most suitable rehabilitation actions for implementation.

Mine team member	Rehabilitation responsibility
	• Approval and sign-off of site-specific rehabilitation actions and reporting.
	• Providing adequate human and financial resources to implement rehabilitation planning.
	• Integrating rehabilitation planning into overall project and mine management.
Environmental Specialist	• Compilation and implementation of rehabilitation plan commitments.
	• Compilation and implementation of annual rehabilitation planning, closure planning and closure-related environmental risk reporting.
	• Compilation, sourcing and purchasing of rehabilitation-related materials and/or services.
	• Undertaking site sampling.
	• Assessment of the performance of rehabilitation actions through implementation of monitoring protocols, and analysis of associated monitoring data
Rehabilitation Specialist and/or Surveyor	• Sign-off and implementation of rehabilitation plans
	• Integrating rehabilitation planning into overall project and mine management.

13.6 Financial resources

Monitoring activities need to be specific cost items on a mine's rehabilitation budget. These cost items must allow for adequate monitoring frequencies, appropriate sampling and analysis methods, and in-depth trend evaluation. Provision must also be made to continue with monitoring until site relinquishment.

Provided concurrent site rehabilitation is being undertaken, inclusion of monitoring costs as part of the annual rehabilitation costs should be seamless.

SECTION D: POST-MINING LAND MANAGEMENT

14. WHY POST-MINING LAND MANAGEMENT?

For any land to have production potential – irrespective of the land use, the soil and plant cover will require ongoing care-and-maintenance. Rehabilitated coal mined land is no different and, could, require even more focus than land unaffected by previous mining activities. Allowance should be made for this ongoing land management as part of the site's transfer agreements to any post-mining landowner/s.

14.1 Understanding changing climates

There are two aspects to consider regarding predictive modelling and climate change. The first is that using historical input data to predict future impacts/interventions in an uncertain climatic future creates its own complexities. The second is that landforms and rehabilitation scenarios must be aimed at outcomes that are climate smart, adaptable and resilient.

For predictive modelling that is aimed at managing a site's residual and latent impacts, a useful exercise is to project data based on the trends in climatic variability experienced over the last decade, and to increase variability over time (up to threshold limits). This should allow for more conservative rehabilitation planning on a defensible basis.

Conducting a site-wide climate change model is useful in identifying rehabilitation aspects that are most at risk. Particularly for final land use considerations, water supply and vegetation species selections.

The impact of changing climates needs to be incorporated into site-wide rehabilitation planning to ensure longer-term resilience of rehabilitation actions

Photo: R. Hattingh 2017

14.2 Creating the best possible land capability for future land use

Changes in natural resource patterns and functions (i.e. the land's physical capabilities) affect what land uses can be implemented. Implementation of certain land uses also affects the patterns and functions of remaining natural resources. Natural and rehabilitated landscape resources can be converted and modified, based on human needs (or desired land uses), and the maintenance of these altered landscapes has a significant impact on the land's ability to continue to provide its goods and services.

Changing land use needs can greatly modify the rehabilitated land's biophysical capabilities

A fundamental aim of mine rehabilitation is to recreate the best possible land capabilities across the rehabilitated site that can enable a multitude of land uses into the future. Land capability implies 'the most intensive use that the land is capable of supporting'. If a mine site is rehabilitated to an arable land potential, it can be used for crops, or grazing, or wildlife, or forestry, or urban development. However, land rehabilitated to a wilderness potential can never sustain good grazing, or cropping, or forestry. The poorer the land capability, the less opportunity for adapting land uses.

**AIM OF MINE REHABILITATION:
TO RECREATE THE BEST POSSIBLE LAND CAPABILITIES THAT CAN ENABLE A MULTITUTE OF LAND USES INTO THE FUTURE**

Mismanagement of rehabilitated land by land users could result in degradation of implemented rehabilitated land capabilities. Ongoing land management therefore suggests some degree of adaptability over time is required.

14.3 Operational rehabilitation to long-term adaptive land management

During the operational phase, rehabilitation actions are used to eliminate or mitigate identified operational and residual environmental risks. Most monitoring activities will also be conducted during the operational, decommissioning and post-mining phases to ensure achievement of implemented interventions, and to identify and implement corrective action where required. The mine's rehabilitation plan and implemented actions should then be able to seamlessly inform conceptualisation of long-term adaptive land management actions for the post-closure phase. These will specifically focus on managing the rehabilitated site's ongoing residual and potential latent environmental risks by the new landowner/s (Figure 18).

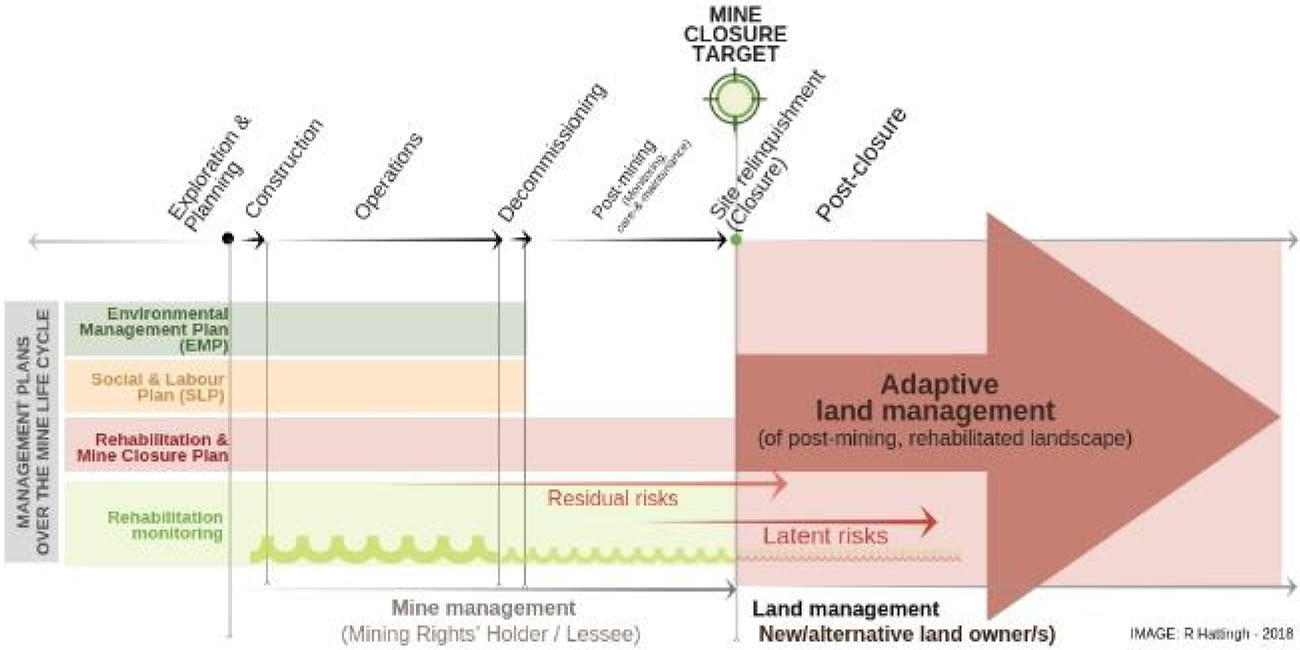


Figure 18: Ongoing land management as part of the entire mining lifecycle, and beyond

The objectives of this post-mining land management planning are as follows:

- To ensure optimal long-term management of the rehabilitated landscape by the new / alternative landowner/s, aligned to the quality of land capabilities achieved by the mine (and demonstrated as being successful prior to site relinquishment);
- To optimally manage the rehabilitated mining landscape's residual and potential latent liabilities into the future, by providing dedicated guidance to the new / alternative landowner/s on successful rehabilitation actions already implemented; and
- To limit the mine's long-term financial responsibility for the rehabilitated landscape, by empowering the new / alternative landowner/s to actively and adaptively manage the residual and latent risks of rehabilitated mine site.

15. FINAL CLOSURE - MANAGING RESIDUAL AND LATENT ENVIRONMENTAL RISKS

"Final closure" is the state whereby the rehabilitated land has reached stability such that the regulators and the interested communities are satisfied that the land will not pose significant additional risk into the long-term future.

SUCCESSFUL REHABILITATION IS THE STATE IN WHICH REHABILITATED LAND IS SUSTAINABLE IN THE LONG-TERM AND CAN SUPPORT AGREED-ON POST-MINING LAND USES. RESIDUAL AND LATENT RISKS ARE ALSO MINIMISED AND CAN BE EFFECTIVELY MANAGED AFTER SITE RELINQUISHMENT.

However, very few mines have received a final closure certificate in South Africa in recent years and the key issue hinges on residual risk and how to manage it. When the mine has completed the rehabilitation actions required and all appears acceptable, the mine wishes to free resources so that it can continue with its key activity of exploiting new mineral reserves. However, the resources must remain tied up in the maintenance of rehabilitated properties until such time as final closure has been granted.

From the legislator's side, the issue is that while the short-term success is evident, there is concern that long-term issues will emerge that will pose a severe and ongoing load on the fiscus – residual and latent risks.

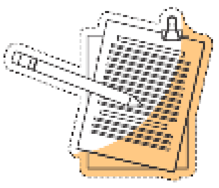
For both residual and latent risks, reluctance to issue closure certificates is related to lack of certainty as to how these issues will be managed in perpetuity.

While the situation with respect to these issues can be closely monitored at the time of application for the closure certificate, the concern of the authorities lies with the potential for development of problems in the future. While modelling and previous experience will provide indications of the probable future of the rehabilitated land, there remain the issue of uncertainty and how to deal with this without loading government with the additional costs associated with the latent defects which may be present.

Due to lack of reliable case studies or long-term site data, predictive modelling is often the preferred means of quantifying relative outcomes of rehabilitation projects. It is particularly useful for comparing different scenarios for rehabilitation, such as levels of vegetation cover, soil cover types and thicknesses, slope angles, surface subsidence, stormwater and geohydrological impacts.

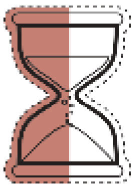
15.1 Managing residual or latent risks

Both residual-and latent risks provide major concern to the authorities. Uncertainty regarding these two risk types is one of the main stumbling blocks to attaining closure certificates.



Example of a residual risk: Presence of invasive species seed in quantities that it will remain sufficiently viable to cause future infestation of the rehabilitated land.

The risk is understood and can be managed by the ongoing application of existing management interventions.



Example of a latent risk: Possibility that, at some stage in the future, water emanating from the rehabilitated land may become acidic.

It is not certain that the waters will turn acidic, but there is a possibility that they could, depending on the relative rates of generation of acid from oxidation of sulphides and of neutralisation from the release of carbonates.

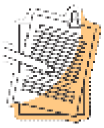
In both cases, there will be a need to manage the risk into the future. How this can be done is a major area for debate, both in South Africa and internationally. One proposed solution is the development of ‘insurance’ funds, where risks can be grouped and covered by the payment of an insurance premium; the other is to have a facility for transferring the liability to an independent third party, who will accept the liability and manage it into the future.

The following are key environmental-related residual and latent risks foreseen to require consideration as part of a mine site’s rehabilitation planning.

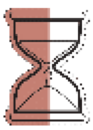
15.1.1 Inability to maintain defined land capabilities due to loss of available soil (growth medium)

Successful implementation of usable land capabilities remains the underpinning aim of land rehabilitation. Prevention or control of any risk event that could affect the integrity of the recreated land capabilities requires attention.

The inability to maintain defined land capabilities due to the loss of available soil resources is due to varying risk events, and could manifest as either a residual or latent risk, as follows:



Surface erosion and/or gully formation due to unmitigated/unmanaged movement of animals across the rehabilitated landscape.



Diffusion and/or capillary rise of salts from underlying spoils into placed cover soils. As the groundwater table rebounds over time in the back-filled pits, the placed soil cover could degrade, manifesting as vegetation die-back and development of bare soil patches that would be susceptible to erosion.

Possible modelling or specialist investigations to help quantify this long-term risk	• Cover soil erosion modelling. • Post-rehabilitation land capability assessments.

15.1.2 Loss of land capability due to settlement

Depressions on back-filled spoils generally develop due to underlying differential settlement, resulting in seasonally or permanently saturated areas on the rehabilitated landscape. This reduces the arable potential of the land as agricultural machinery required for high productivity cropping cannot operate on undulating, waterlogged topographies. The waterlogged conditions may also inhibit vegetation growth suitable for grazing and pasture-related land uses.

This risk could result from:

Changes to the physical properties of the materials (soil, overburden, etc.) that have been 're-assembled' as part of the rehabilitated landform profile.

Changes to the soil chemistry (specifically changes to sodium potential) of replaced soils.

Possible modelling or specialist investigations to help quantify this long-term risk	• Post-rehabilitation land capability assessments. • Assessment of landform topography design criteria and conformance to this plan to assess probability of secondary subsidence.

15.1.3 Loss of surface water yield (catchment integrity) due to settlement

Surface ponding resulting from surface settlement could also increase the recharge rate of water through the backfilled open pit spoils. Although this recharge could also be the result of a poor soil and vegetation cover, this ingress can result in the following:

Reduction in local catchment yield as surface water that should have been routed towards local water resources is now constricted by surface ponding and spoil ingress.

Increase volumes of water that may require long-term water treatment should it manifest on-surface as contaminated decant.

Possible modelling or specialist investigations to help quantify this long-term risk	• Post-rehabilitation land capability assessments (specifically on cover integrity). • Assessment of landform topography design criteria and conformance to this plan to assess probability of secondary subsidence. • Monitoring data analysis of actual water quantities manifesting at decant locations, as compared to modelled volumes.

15.1.4 Loss of established vegetation affecting land use potential

Growth and the associated yield of the established vegetation cover will affect the manner and intensity of which the rehabilitated landscape can be used. Loss of established vegetation could result from:

Excessive/unmitigated animal grazing and/or movement across the rehabilitated landscape.

Diffusion and/or capillary rise of salts from underlying spoils into placed cover soil.

Possible modelling or specialist investigations to help quantify this long-term risk	• Vegetation surveys. • Post-rehabilitation land capability assessments.

15.1.5 Lack of long-term availability of water for desired land use/s that require water supply (livestock watering, pasture or crop irrigation, etc.)

Most post-mining land uses will require some form of water to sustain the desired land capabilities. This may either mainly be to maintain watering areas (troughs) for animal production, irrigation points for crop production, and/or fresh water resources for human livelihood use. However, much uncertainty exists around both long-term ground water qualities and quantities within rehabilitated mine sites (as there is usually insufficient funds spent on the required modelling and monitoring activities).

This latent risk could manifest due to the following risk events:

Unpredicted/unplanned deterioration or variance of groundwater qualities as potential groundwater plumes migrate outside of the rehabilitated pit boundaries.

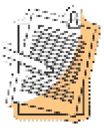
Lack of control of natural groundwater recharge rates, or variances from predicted rates, affecting the ability to maintain predefined land capabilities.

Unmitigated/unplanned use of groundwater by either upstream or downstream water users that affects the mine's planned/predicted water use/s (qualities and quantities).

Possible modelling or specialist investigations to help quantify this long-term risk	• Geohydrological modelling, over time (continually calibrated with monitoring data) - to define and monitor the probable extent of the pollution plume and its likely pollutant content. • Pump tests of remaining boreholes (of both monitoring and functional boreholes).

15.1.6 Lack of maintenance of retained surface infrastructure by new owner/s

This residual risk is deemed manageable prior to mine closure, provided long-term infrastructure management actions are provided to the new landowner/s. However, experience over the past decade



within the South African mining industry has indicated that the long-term management of transferred surface infrastructure from mines to new landowners has generally been poor. This is due mainly to the lack of management skills and resources (human and financial) available within local municipalities and communities to which the infrastructure has been transferred.

Should surface infrastructure be retained for future handover to new owner/s, some form of contingency financing for the eventuality that the new owners do not manage the infrastructure properly and abandon it should be in place.

Possible specialist investigations to help quantify this long-term risk	• Dedicated risk assessment to determine actual feasibility (environmental, financial, health-and-safety, reputational, etc.) of retaining infrastructure as opposed to demolition. • Skills assessment within local and regional municipalities to determine capabilities to both physically and financially manage infrastructure and related services.

The above is not an exhaustive list of possible ongoing residual and latent risks that may manifest from the rehabilitated mine site. Site-specific rehabilitation planning, risk assessments, rehabilitation action implementation and monitoring will enable identification of site-specific risks for discussion with closure decision makers.

15.2 Financial provisioning for residual and latent risks

The manner in which financial provision is made for residual and latent risks will vary depending on the life-of-mine phase.

During the operational phase (including decommissioning and the monitoring phases), rehabilitation actions will be focussed on identifying and controlling residual risks. This may increase the financial expenditure required to manage overall site risks - up and above identified environmental risks that can be mitigated. However, as the mine is still operating, these costs can be built into the site's annual concurrent rehabilitation costs.

Once the site has been relinquished (post-closure), allowance will need to be made for:

- Long-term management of ongoing residual risks. The mine should have a good understanding of the ongoing care-and-maintenance requirements of these risks and will be able to accurately quantify human capital and financial provision requirements.
- Possible, future latent risks. As there will be uncertainty as to the likelihood and severity of these risks occurring, at closure there will also be uncertainty around their longer-term (human and financial capital) management needs.

This Guideline acknowledges that the tools available to the mining industry – both in South African and internationally, at the time of publication are inadequately assisting industry to accurately quantify latent risks. There is a need for some form of actuarial, financial vehicle – insurance or banking, to define and quantify latent risks and associated financial provisioning required to manage a site's risks into the future.

However, this uncertainty emphasises the importance of development of a well thought-through Adaptive Land Management Plan for handover to the new landowner/s.

15.3 Post-Mining Land Management Plan

A Post-Mining Land Management Plan should be compiled as the site nears application for a closure certificate. This will be based specifically on the monitoring trends documented during the post-mining maintenance period, and aligned to the recreated post-mining land capabilities and overarching predicted land use/s.

This plan should clearly emphasise that the rehabilitated land in more sensitive than normal land and provide care-and-maintenance activities required to encourage future land users not to exceed what the rehabilitated land can deliver.

This plan should be incorporated into the rehabilitated land's Title Deed sale/transfer, for implementation by the new landowner. It is aimed at both helping the new landowner/s appropriately manage and use the rehabilitated landscape, as well as reduce the legislative-driven long-term management and financial liability to which a mine is exposed after receipt of a closure certificate.

Rehabilitated coal mine in the Mpumalanga Province, on which ongoing adaptive land management of pastureland is a daily activity

This Post-Mining Land Management Plan should clearly detail residual site risks, as well as the potential for predicted / modelled latent environmental risks. It should explain the risks' causes, already implemented rehabilitation actions (if applicable), quantified preventative actions, and future corrective actions.

The following is an example of what should, at least, be included in such a plan:

- Identification of specific rehabilitated areas that should not be exposed to human and/or animal movement, such as rehabilitated tailings facilities. These may be temporary time restrictions.
- Fertilisation requirements of specific species to ensure a healthy sward. Exact fertilisation frequencies, seasonality, and quantities and ratios of LAN fertiliser, and (calcitic or dolomitic) lime if necessary, would be in accordance with specifications generated from post-rehabilitation land capability assessments.
- Defoliation requirements of specific species, via controlled grazing, manual cutting and/or burn regimes.
- Control protocols of declared weeds and invader plant species.
- Animal stocking rates (carrying capacities) to manage potential for over-grazing where livestock production is a defined land use.

- Control grazing regimes in rehabilitated wetlands and/or other ecologically sensitive areas.
- An indication of where infrastructure can and cannot be constructed (such as over unconsolidated spoils).
- Identification of areas where groundwater contamination from the rehabilitated mine site may be present. Includes expected (mathematically modelled) rebound levels, decant locations and contamination plume movement.
- Delineation of exclusion zones where new boreholes cannot be drilled due to the potential draw-down effect they may have on groundwater plumes (both for the new user's information and regulators that will be responsible for the approval and licencing of future groundwater abstraction). Private boreholes and/or springs that could be affected by plume movement should also be highlighted.
- Documentation of any ongoing commitments for potable water supply, including off-take users, pump volumes and rates, maximum allotted quotas, etc.
- Any specific ongoing requirements for dedicated surface- and groundwater monitoring that will need to remain in place to continue to monitor effects of natural groundwater recharge levels and rates, future decant locations, as well as changes water qualities due to the SO_4 plume movement and decant manifestation.

Monitoring borehole identified to be retained in the rehabilitated landscape, for ongoing water use

Any activities and associated maintenance related to day-to-day farming or other predefined activities would remain the onus of the new landowner. It is assumed that State, via its environmental, land and water authorities would retain responsibility for state-managed actions, such as catchment water monitoring.

Hence, the Post-Mining Land Management Plan would be compiled purely to manage residual and latent environmental risks directly related to the specified mining activities.

Land Rehabilitation Guideline for Surface Coal Mined Land

APPENDICES

Appendix A: GUIDELINE ABBREVIATIONS AND TERMS

The following abbreviations and terms are used throughout this Guideline:

Abbreviation or Term	Definition
Brownfields	A property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant[44]
CARA	Conservation of Agricultural Resources Act, No. 43 of 1983 (South Africa)
Care-and-maintenance	The post-mining period (after cessation of mining activities, and final decommissioning), during which ongoing monitoring and maintenance activities are undertaken. This period is used to demonstrate achievement of committed-to relinquishment criteria.
Closure	The point in time when all decommissioning and rehabilitation activities have ceased, monitoring has been completed and the mine applies for a closure certificate
Coaltech	Coaltech Research Association (South Africa)
DAFF	Department of Agriculture, Forestry and Fisheries (South Africa)
Decommissioning	The period directly after cessation of operational activities (i.e. when the last mineral reserve has been extracted). It includes reclamation, rehabilitation and/or restoration of any final remaining areas (e.g. backfilling of final ramps and voids, landform shaping, topsoiling and seeding), as well as removal of all operation-related equipment that has no beneficial re-use potential
DWS	Department of Water and Sanitation (South Africa), (previously referred to as the Department of Water Affairs (DWA))
EA	Environmental Authorisation
EAP	Environmental assessment practitioner
EHS Guidelines	Environmental, Health and Safety Guidelines (IFC/World bank)
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
Environment	The surroundings within which humans exist and that are made up of – (i) the land, water and atmosphere of the earth; (ii) micro-organisms, plant and animal life; (iii) any part or combination of (i) and (ii) and the interrelationships among and between them; and (iv) the physical. chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being[45]

[44] United States Environmental Protection Agency (https://www.epa.gov/brownfields/brownfield-overview-and-definition)

[45] National Environmental Management Act, No. 107 of 1998

Abbreviation or Term	Definition
Environmental management plan	A plan to manage and rehabilitate the environmental impact as a result of prospecting, reconnaissance, exploration or mining operations conducted under the authority of a reconnaissance permission, prospecting right, reconnaissance permit, exploration right or mining permit, as the case may be[46]
Financial provision	The insurance, bank guarantee, trust fund or cash that applicants for or holders of a right or permit must provide in terms of sections 41 and 89 guaranteeing the availability of sufficient funds to undertake the agreed work programmes and to rehabilitate the prospecting, mining, reconnaissance, exploration or production areas, as the case may be[47]
Greenfields	An area of agricultural or forest land, or some other undeveloped site earmarked for commercial development or industrial projects
I&APs	Interested and Affected Parties
ICMM	International Council on Mining and Metals
IFC	International Finance Corporation
Land capability	The ability of the land to sustain a type of land use permanently. The key is matching the type and intensity of land use (arable, grazing, etc) with the natural capability of the land[48]
Land capability classification	A system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time
Land cover	The classification of land according to the vegetation or material that covers most of its surface[49]
Landform	A natural feature of the solid surface of the earth. Landforms together make up a given terrain, and their arrangement in the landscape is known as topography. Landforms are categorised by characteristic physical attributes such as elevation, slope, orientation, stratification, rock exposure, and soil type[11] Landforms in a rehabilitated mining landscape generally refer to the back-filled (or unfilled) pits, and designed and re-profiled surfaces of the remaining waste dumps / facilities.
Land management	System of regulating and managing land use and conferring land use rights through the use of schemes and land development procedures[47]
Landscape	
Land stewardship	Responsibility for sustainable development shared by all those whose actions affect environmental performance, economic activity, and social progress, reflected as both a value and a practice by individuals, organisations, communities, and competent authorities[50]

[46] Minerals and Petroleum Resources Development Act, No. 22 of 2002
[47] Spatial Planning & Land Use Management Act, No. 16 of 2013 (South Africa)
[48] New South Wales Local Land Services: https://www.lls.nsw.gov.au/agriculture/land-capability
[49] ESRI
[50] ISO 20121 (par..3.20)

Abbreviation or Term	Definition
Land use	The purpose for which land is or may be used lawfully in terms of a land use scheme, existing scheme or in terms of any other authorisation, permit or consent issued by a competent authority, and includes any conditions related to such land use purposes[47]
Land use management system	System of regulating and managing land use and conferring land use rights through the use of schemes and land development procedures[47]
LaRSSA	Land Rehabilitation Society of Southern Africa
LOM	Life-of-mine
MinCoSA	Minerals Council of South Africa, (previously referred to as the South African Chamber of Mines)
Mine closure	The point in a mine's lifecycle at which sign-off of the rehabilitated land to a new/alternative owner is achieved, and a closure certificate is issued to the mining company
MPRDA	Mineral and Petroleum Resources Development Act, No. 22 of 2002 (South Africa)
MR	Mining Right
MRCP	Mine reclamation and closure plan (Australia)
NEMA	National Environmental Management Act, No. 107 of 1998 (South Africa)
NEMA GNR1147	NEMA, Government Notice Regulation 1147 Pertaining to the Financial Provision for Prospecting, Explorations, Mining or Productions Operations, dated 20 November 2015
NWA	National Water Act, No. 26 of 1998 (South Africa)
SLP	Social and Labour Plan
Post-mining	The period during which any final reclamation, rehabilitation and/or restoration is carried out to achieve the planned closure vision. This includes active monitoring of implementation success, as well as application of corrective action, where required
Post-mining land use	A land use which occurs after the cessation of mining operations[51]
Reclamation	Treatment of previously degraded and often contaminated land to achieve a useful purpose[51]
Regeneration	Consideration of broad socio-economic and environmental aspects so that the post-disturbed landscape can return economic and ecological benefits to off-set negative closure impacts[52]
Region	In relation to a regional spatial development framework, means a circumscribed geographical area characterised by distinctive economic, social and natural features which may or may not

[51] Australian Department of Resources, Energy and Tourism (2011)
[52] Post-mining Alliance (http://www.postmining.org/index.php - January 2015)

Abbreviation or Term	Definition
	correspond to the administrative boundary of a province or provinces or a municipality or municipalities[47]
Rehabilitation	The return of disturbed land to a stable, productive and self-sustaining condition, consistent with the post-mining land use[53]
Relinquishment	Transfer of responsibility for caring for the area to a third party, usually after compliance with legal obligations and relinquishment criteria
Relinquishment criteria	Defined parameters, indicators or conditions that must be met so that rehabilitation objectives can be considered as fulfilled. They will generally be in the form of numerical values that can be verified by measurement of the indicators selected for the rehabilitation objectives
Remediation	To clean-up or mitigate contaminated soil or water[51]
Restoration	Putting back the original ecosystem's function and form[52]
Risk	Uncertain future events that could affect or hinder achievement of the rehabilitation objectives, as determined from the likelihood of their occurrence and resultant impacts
Latent risk	A risk that may or may not result or manifest after actions for final rehabilitation, decommissioning and closure have been implemented[54], and that affects achievement of stipulated rehabilitation objectives. (For example, secondary subsidence of the rehabilitated land surface profile which may or may not occur when the groundwater levels naturally re-establish).
Residual risk	A risk which remains after rehabilitation is complete. (For example, the lower availability to plants of soil nitrogen due to the lower levels of soil organic matter present in rehabilitated profiles).
SLP	Social and Labour Plan
SPLUMA	Spatial Planning and Land Use Management Act, No. 16 of 2013 (South Africa)
Sustainable development	The integration of social, economic and environmental factors into planning, implementation and decision making so as to ensure that mineral and petroleum resources development serves present and future generations[46]

[53] Australian Department of Mines and Petroleum (2010)
[54] NEMA GNR1228 (10 November 2017)

Appendix B: RELEVANT LAND REHABILITATION LEGISLATIVE REQUIREMENTS

Global context

A global rehabilitation governance context is provided below. The aim of this is to highlight key documents – guidelines, toolkits, standards, etc., that are available to guide a land practitioner when compiling a mine's rehabilitation plan. South Africa is a signatory to a number of these international conventions and/or governing bodies, which make it obligatory for South African mining companies to adopt the guidance provided by these bodies when determining domestic policy and legislation (for example on environmental rehabilitation obligations which should be imposed on mining companies).

International conventions and treaties

Since 1994 South Africa, in its commitment to promoting democracy, peace and security, environmental protection, sustainable development and poverty eradication has acceded to and ratified a number of additional conventions and protocols that enable it to promote the global sustainable development agenda. These are particularly in terms of issues related to sustainable development and trade, climate change, chemicals and waste management, biodiversity, and activities that affect the world's oceans and marine environment. Accordingly, the following conventions and treaties should be considered when setting a site's long-term rehabilitation objectives:

- The United Nations Conference on Sustainable Development (UNCSD) and Rio 2012, Rio+20, being the third international conference on sustainable development aimed at reconciling the economic and environmental goals of the global community.
- United Nations Framework Convention on Climate Change (UNFCCC), New York, 9 May 1992. Specifically:
  - Kyoto Protocol to the UNFCCC, Kyoto, 11 December 1997;
  - Amendment to Annex B of the Kyoto Protocol to the United Nations Framework Convention on Climate Change, Nairobi, 17 November 2006;
  - Doha amendment to the Kyoto Protocol, Doha, 8 December 2012; and
  - Paris Agreement, Paris, 12 December 2015
- Convention on Biological Diversity. Rio de Janeiro, 5 June 1992 (CBD) and Cartagena Protocol on Biosafety, Montreal, 29 January 2000
- United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, (UNCCD) Particularly in Africa, Paris, 14 October 1994.

Tools, standards, rehabilitation drivers

Some international initiatives often driven by NGOs, for example EITI, have informed the disclosures needed for transparency in mining. Societal values, in particular the value ascribed to the environment and life quality, are focusing the minds of communities on ensuring that future mining achieve better conservation of the environment, long-term management of natural resources, and fair social-economic impacts in the life of local communities.

Apart from treaties and protocols further global drivers emerge from requirements imposed by international funders like the World Bank and IFC in the form of Guidelines (www.ifc.org/ehsguidelines).

The IFC Performance Standards - include Performance Standards on issues such as:1 - Assessment and Management of Environmental and Social Risks and Impacts,- Labour and Working Conditions,- Resource Efficiency and Pollution Prevention,- Community Health, Safety and Security, Land Acquisition and Involuntary Resettlement, Biodiversity Conservation and Sustainable Management of Living Natural Resources, Indigenous Peoples and Cultural Heritage

The World Bank Group Environmental, Health, and Safety Guidelines (EHS Guidelines) are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP), as defined in IFC's Performance Standard 3: Resource Efficiency and Pollution Prevention. IFC uses the EHS Guidelines as a technical source of information during project appraisal activities, as described in IFC's Environmental and Social Review Procedures Manual. The EHS Guidelines contain the performance levels and measures that are normally acceptable to IFC, and that are generally considered to be achievable in new facilities at reasonable costs by existing technology. They are divided into sections entitled: Environmental; Occupational Health and Safety; Community Health and Safety; Construction; and Decommissioning. They should be used together with the relevant Industry Sector Guideline(s).: See with particular reference to mining the EHS Guidelines for Mining.

The Equator Principles (June 2013) is a financial industry benchmark for determining, assessing and managing environmental and social risk in projects to be funded by the merchant banks(www.equator-principles.com). It would have relevance to any global mining projects funded in this manner. It also makes use of the IFC standards etc. It includes requirements necessitating EI&SA and reporting criteria. It provides for an Environmental and Social Management Plan (ESMP) which summarises the client's commitments to address and mitigate risks and impacts identified as part of the Assessment, through avoidance, minimisation, and compensation/offset. This may range from a description of routine mitigation measures to a series of more comprehensive management plans (e.g. water management plan, waste management plan, resettlement action plan, indigenous peoples plan, emergency preparedness and response plan, decommissioning plan). The level of detail and complexity of the ESMP and the priority of the identified measures and actions are commensurate with the Project's potential risks and impacts. The ESMP definition and characteristics are broadly similar to those of the "Management Programs" referred to in IFC Performance Standard. The Assessment document required provides for an assessment on the protection and conservation of biodiversity (including endangered species and sensitive ecosystems in modified, natural and Critical Habitats) and identification of legally protected areas. Critical Habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes. The Equator Principles Association was formed on 1 July 2010 and it is governed by a set of Governance Rules which provide guidance to existing and prospective EPFIs on the processes for the management, administration and development of the Equator Principles.

The Extractive Industries Transparency Initiative (EITI) is a global standard for the good governance of oil, gas and mineral resource by inter alia s encouraging high standards of transparency and accountability in public life, government operations and in business. It seeks to address the key governance issues in the extractive sectors. The 12 EITI Principles provide the cornerstone of the initiative for example EITI Requirement 2 deals with Legal and institutional framework, including allocation of contracts and Overview: The EITI requires disclosures of information related to the rules for how the extractive sector is managed, enabling stakeholders to understand the laws and procedures for the award of exploration and production rights, the legal, regulatory and contractual framework that apply to the extractive sector, and the institutional responsibilities of the State in managing the sector. The EITI Requirements related to a transparent legal framework and award of extractive industry rights include: (2.1) legal framework and fiscal regime; (2.1) license allocations (2.3) register of licenses; (2.4) contracts; (2.5) beneficial ownership; and (2.6) state-participation in the extractive sector. Under 2.1 Legal framework and fiscal regime, the implementing countries must disclose a description of the legal framework and fiscal regime governing the extractive industries. This information must include a summary description of the fiscal regime, including the level of fiscal devolution, an overview of the relevant laws and regulations, and information on the roles and responsibilities of the relevant government agencies

International mining industry developed protocols and standards - for example *ICMM – 10 Principles for Sustainable Mining* Principle 6 requires member companies pursue continual improvement in environmental performance issues, such as water stewardship, energy use and climate change. They also require member companies to assess positive and negative, direct and indirect, and cumulative environmental impacts of new projects – from exploration to closure. Implement an environmental management system of continual improvement to review, prevent, mitigate or ameliorate adverse environmental impacts. Rehabilitate land disturbed or occupied by operations in accordance with appropriate post-mining land uses. Provide for safe storage and disposal of residual wastes and process residues. Design and plan adequate resources to meet the closure requirements of all operations. Principle 7 Contribute to the conservation of biodiversity and integrated approaches to land-use planning Respect legally designated protected areas. Disseminate scientific data on and promote practices and experiences in biodiversity assessment and management. Support the development and implementation of scientifically sound, inclusive and transparent procedures for integrated approaches to land-use planning, biodiversity, conservation and mining.

See also the ICMM Mapping Mining to the SDGs: An Atlas and the ICMM Planning for Integrated Mine Closure Toolkit.

Other drivers where mining laws and the legal and technical capacity may be lacking in some countries can focus on internationally recommended good mining practices (ALSF, 2017; AMLA, 2017). Mining companies more especially those that are listed on stock exchanges are also driven by obligations which may come both from funders of such projects or from the listing requirements of the exchanges or indices under which they are listed to adopt good mining procedures according to the best international standards. NGO driven programmes that influence company behaviours e.g. on carbon reporting or Water Stewardship through organisations like the World Business Council (WBCSD) &NBI in SA actively work to facilitate projects on water in South Africa. Partnerships formed with for example the CEO Water Mandate have advanced water stewardship practice across Southern Africa. The World Business Council for Sustainable Development is a CEO-led, global advocacy association of some 200 international companies dealing exclusively with business and sustainable development.

Other reports and work done internationally by NGOs can also inform the development of rehabilitation requirements for example " Dead Planet, Living Planet: Biodiversity and Ecosystem Restoration for Sustainable Development a Report by UNEP which underlines that far from being a tax on growth and development, many environmental investments in degraded, nature-based assets can generate substantial and multiple returns. These include restoring water flows to rivers and lakes, improved soil stability and fertility vital for agriculture and combating climate change by sequestrating and storing carbon from the atmosphere. Its recommendations including: Urging overseas development agencies, international finance agencies and other funders – such as regional development banks – to factor ecosystem restoration and long-term management assistance into development support, food security initiatives, job creation and poverty alleviation funding. Ecosystem restoration should be guided by experiences learnt to date to avoid unintended consequences, such as the introduction of alien invasive species and pests. Priority be given to biodiversity and ecosystem "hotspots." Infrastructure projects that damage an ecosystem have funds set aside to restore a similar degraded ecosystem elsewhere in a country or community[55].

[55] Felleman, Christian & Corcoran, Emily. Dead Planet, Living Planet: Biodiversity and Ecosystem Restoration for Sustainable Development, Text, 2010; Nairobi, Kenya. (digital.library.unt.edu/ark:/67531/metadc28586/: accessed November 7, 2017), University of North Texas Libraries, Digital Library, digital.library.unt.edu).

SOUTH AFRICAN CONTEXT

Mining legislation

Reg 62 of the MPRDA Regs sets out the content requirements of a closure plan which must include a record of I&AP consultation and technical appendices. The closure plan must have closure objectives and how these relate to the prospecting or mine operation and its environmental and social setting; a plan contemplated in regulation 2 (2), showing the land or area under closure, a summary of the regulatory requirements and conditions for closure negotiated and documented in the EMP, a summary of the results of the environmental risk report and details of identified residual and latent impacts; a description of the methods to decommission each prospecting or mining component and the mitigation or management strategy proposed to avoid, minimize and manage residual or latent impacts; details of any long-term management and maintenance expected; a sketch plan drawn on an appropriate scale describing the final and future land use proposal and arrangements for the site details of a proposed closure cost and financial provision for monitoring, maintenance and post closure management.

Environmental legislation

Assessment of environmental impacts of mining during all phases for environmental authorisation (EA)

A mining right applicant must submit various documents in support of the application. This would include a Regulation 2(2) plan (layout plan), mining works programme (MWP) and social and labour plan. Once the application is accepted, the various environmental reports and consultation must be done in order to obtain an environmental authorisation (EA). A separate EA application is required which must first be issued before the mining right is issued. The obtaining of an EA must be done in accordance with the requirements in NEMA and this requires there be an environmental assessment of the impacts of the proposed mining through all phases from construction to closure and post-closure and the preparation of an environmental management programme (EMP) in accordance with procedure in the NEMA and 2014 EIA Regs. The granting however of the EA and the approval of the EMP as a component thereof is done by the Minister of Mineral Resources as part of the application made for a mining right. NEMA s24 and the current 2014 EIA Regulations determine how this should be done.

Since every holder of an authorisation must manage and implement such procedures and requirements in respect of the closure of a mine as may be prescribed, a closure plan as contemplated in Appendix 5 of the 2014 EIA Regulations would also need to be prepared and adhered to. The mining proponent would need to determine the amount and make the necessary financial provision as contemplated in s 24P and the financial provisioning regulations 2015.

Environmental Authorisation, Environmental Management Programme with Closure Plan determine rehabilitation commitments and financial provision

For any new opencast coal mine an application for a mining right would need to include a site layout plan (Regulation 2 of the MPRDA Regulations) a mining works programme which details the mineral deposit, time frames and schedules for the proposed opencast mining of such deposit. The application for an EA (which authorisation would include, as a component thereof, a proposed environmental management programme (EMP)) would be submitted to the Regional Manager of region within which the mining is proposed for authorisation by the Minister for Mineral Resources, before the commencement of mining operations can happen. As part of this there would need to be compliance with the requirements of s 24N on the content of the EMP, and with 24P of NEMA on financial provision - which requires that before the issuing of the authorisation the requisite financial provision must be in place. Any such determination of the financial provision must be made in accordance with what is provided in the regulation on financial provisioning. (FP Regulation 2015).

For existing operators that have a mining right and an approved EMP, a review can be required of the EMP and revision is required to be done of the quantum of the financial provision that has been made. This quantum was required to be revisited annually or as required by the EMP in accordance with what was provided in the now repealed regulations 54 and 55 of the MPRDA Regulations. With effect from February 2019 this review of quantum would need to be done in accordance with what is provided for in the FP Regulations 2015 as amended in 2016.

Rehabilitation must be an integral part of opencast mining

NEMA section 24N governs what must be contained in the EMP and this includes a requirement that details of the measures to rehabilitate the environment affected by the mining to its natural or pre-determined state or to a land use which conforms to generally accepted principles of sustainable development must appear in the EMP.(s24N(2)(f)). It is clear from s 24N(7) that management of environmental impacts must be done in accordance with what is provided in the approved EMP and must be done as an integral part of the mining operation (unless directed otherwise). This would mean that any surface rehabilitation requirements necessary for mining coal by open cast operations would be regarded as an integral part of such opencast mining operations and these must, far as is practicable, be conducted concurrently with such operations and in accordance with what is provided in the EMP.

The EMP with the any rehabilitation commitments as maybe identified in the programme becomes binding on the operator with the grant of the EA. The mining works programme and the EMP, should be aligned in terms of how the mining works progress and how the rehabilitation of the affected areas is to be done. In practice therefor the site plan and the EMP and any closure plan are crucial in that they form the basis of the terms and conditions (conditionalities) under which the mining right and EA are given and how the mining and rehabilitation must progress. A failure to adhere to such programmes carries with it the consequences that are outlined both in the MPRDA in section 23(6) and section 47 and in the NEMA and 2014 EIA Regulations. After approval by the Minister of the EMP, it becomes enforceable, and rehabilitation must be carried out in accordance therewith.

Performance assessment and reporting is required to be done against the EMP (s24N(7)(d), and its obligations and commitments and a wide discretionary power in determining what may be done as regards any failure to rehabilitate disturbed land in accordance therewith, is provided in the NEMA.

Financial provision determined and made

Specific provisions in the FP Regs 2015 contemplate the purpose of the regulations is to determine FP (in other words a calculation on funding quantum) and then the making of the FP. FP is for 2 types of costs - the costs associated with undertaking management, rehab and remediation of environmental impacts through the lifespan of operations and costs for latent and residual impacts which become known in the future.

There are implications for having to provide funding for ongoing rehabilitation by mining companies. Operators must prepare an annual rehabilitation plan, final rehabilitation, decommissioning and mine closure plan and ERAR which form a component of the EMP as well form the basis for determining the costs of implementing such plans. This makes up the FP calculation. These plans and calculations are subject to review and audit similar to requirements on performance and audit as is there for the EMP.

Appendices to the FP Regulations include minimum requirements on the content of the annual rehabilitation, the final rehabilitation, decommissioning and mine closure plan

<u>Water legislation</u>

GN704 aimed specifically at the prevention of water pollution by mining

The Water Minister can make regulations for the prevention of water pollution. GN R.704 is with many prescriptions on the use of water for mining and related activities aimed at the protection of water resources the key regulation under the NWA affecting mining including coal mining and rehabilitation. It indicates what must be contained in the EMP with specific regard to mine water management and measures to prevent water pollution from occurring such as separating clean and dirty water sources. Duties like informing DWS of new activities or changes in EMP. Restrictions are imposed on locating infrastructure including MRDs near any water resource. Measures are required by persons in control of mines to prevent leaching which can cause water pollution.

Wastewater measures under GN704

Measures are required to prevent wastewater likely to cause pollution from entering any water resource, either by natural flow or by seepage, and mine operators must retain or collect such substance or water containing waste for use, re-use, evaporation or for purification and disposal. Obligations relate to design, modify, locate, construct and maintain all water systems, including residue deposits, in any area so as to prevent the pollution of any water resource through the operation or use thereof and to restrict the possibility of damage to the riparian or in-stream habitat through erosion or sedimentation, or the disturbance of vegetation, or the alteration of flow characteristics. Effective measures must be taken to minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns, through cracked or fissured formations, subsided ground, sinkholes, outcrop excavations, adits, entrances or any other openings. Obligation relate to design, modify, construct, maintain and use any dam or any residue deposit or stockpile used for the disposal or storage of mineral tailings, slimes, ash or other hydraulic transported substances, so that the water or waste therein, or falling therein, will not result in the failure thereof or impair the stability thereof.

Water infrastructure under GN 704

Mine operators must prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources and ensure that water used in any process at a mine or activity is recycled as far as practicable, and any facility, sump, pumping installation, catchment dam or other impoundment used for recycling water, is of adequate design and capacity to prevent the spillage, seepage or release of water containing waste at any time and at all times keep any water system free from any matter or obstruction which may affect the efficiency thereof. All domestic waste, including wash-water, which cannot be disposed of in a municipal sewage system, must be disposed of in terms of an authorisation under the Act.

Security, fencing and notices under GN 704

Mine operators must cause any impoundment or dam containing any poisonous, toxic or injurious substance to be effectively fenced-off to restrict access, and must erect warning notice boards warn persons of the hazardous contents thereof; (b)ensure access control in any area used for the stockpiling or disposal of any residue or substance which causes, has caused or is likely to cause pollution of a water resource so as to protect any measures taken in terms of these regulations;(c)not allow the area contemplated in paragraph (a) and (b) to be used for any other purpose, if such use causes or is likely to cause pollution of a water resource; and(d)protect any existing pollution control measures or replace any existing pollution control measures deleteriously affected, damaged or destroyed by the removing or reclaiming of materials from any residue deposit or stockpile, and establish additional measures for the prevention of pollution of a water resource which might occur, is occurring or has occurred as a result of such operations.

Safeguards on temporary or permanent cessation of mine or activity under GN 704

Mine operators must, at either temporary or permanent cessation of operations, ensure that all pollution control measures have been designed, modified, constructed and maintained so as to comply with these regulations and must ensure that the in-stream and riparian habitat of any water resource, which may have been affected or altered by a mine or activity, is remedied so as to comply with these regulations. On either temporary or permanent cessation of a mine or activity the Minister may request a copy of any surface or underground plans.

Technical investigation and monitoring under GN 704

Technical investigations may be required of the mine operator, after an inspection and an independent review, may be required to be conducted on any aspect aimed at preventing pollution or damage to the in-stream or riparian habitat The Minister may require a mine operator to submit a programme of implementation to prevent or rectify any pollution as recommended by the investigation contemplated. The Minister may in writing direct such person implement a compliance monitoring network to monitor the programme of implementation, through establishing, operating and maintaining monitoring installations of a type, at the locations and in the manner specified and to submit the monitoring information and results to the Minister for evaluation.

Information to be provided under GN 704

Mine operators must submit plans, specifications and design reports approved by a professional engineer to the Minister, not later than 60 days prior to commencement of activities relating to—the construction of any surface dam for the purpose of impounding waste, water containing waste or slurry, so as to prevent the pollution of a water resource; the implementation of any pollution control measures at any MRDS so as to prevent the pollution of a water resource; and the implementation of any water control measures at any MRDS, so as to prevent the pollution of a water resource.

Specific measures for coal residue deposits under 704

Most importantly for coal mining rehabilitation regulation 11 of 704 sets out additional regulations for rehabilitation of coal residue deposits. Persons mining or establishing coal residue deposits must rehabilitate such residue deposits so that all residue deposits are compacted to prevent spontaneous combustion and minimise the infiltration of water; and the rehabilitation of the residue deposits is implemented concurrently with the mining operation.

<u>Agricultural land legislation</u>

The objects of the Conservation of Agricultural Resources Act 43 of 1983 (CARA) are to provide for the conservation of the natural agricultural resources of SA by the maintenance of the production potential of land, by the combating and prevention of erosion and weakening or destruction of the water sources, and by the protection of the vegetation and the combating of weeds and invader plants. This Act provides for the prescribing of control measures by the Minister which measures have to be complied with by land users to whom they apply. However, the definition of land user" whilst meaning the owner of land, (and includes any person who has a personal or real right in respect of any land, irrespective of whether he resides thereon); is not a person who carries on prospecting or mining activities. A person carrying on mining activities would not be a land user to whom CARA would apply. Once mining activities cease it is arguable that the continued ownership of the land may well give rise to obligations under CARA like control measures being imposed. These then be binding on the erstwhile mine owner.

Control measures may relate to—(a)the cultivation of virgin soil;(b)the utilization and protection of land which is cultivated;(c)the irrigation of land;(d)the prevention or control of waterlogging or salination of land;(e)the utilization and protection of vleis, marshes, water sponges, water courses and water sources;(f)the regulating of the flow pattern of run-off water;(g)the utilization and protection of the vegetation;(h)the grazing capacity of veld, expressed as an area of veld per large stock unit;(i)the maximum number and the kind of animals which may be kept on veld;(j)the prevention and control of veld fires;(k)the utilization and protection of veld which has burned;(l)the control of weeds and invader plants;(m)the restoration or reclamation of eroded land or land which is otherwise disturbed or denuded;(n)the protection of water sources against pollution on account of farming practices;(o)the construction, maintenance, alteration or removal of soil conservation works or other structures on land; and(p)any other matter necessary or expedient in order that the objects of this Act may be achieved. A direction order may be issued to a land user to comply with a particular control measure which is binding on him on or with regard to the land specified in such direction. Directions either need to be published by a gazetting of it or served on the land user. Any direction which was declared applicable with regard to land under section 3, 4 or 7 of the Soil Conservation Act, 1969 (Act No. 76 of 1969), in force at the commencement of this section, was deemed to be a direction which has been served in terms of this section on the land user in respect of the land mentioned therein. Similarly any notice given under section 2 of the Weeds Act, 1937 (Act No. 42 of 1937), or any order issued in terms of section 5bis of that Act in force at the commencement of this section, was deemed to be a direction served in terms of this section on the land user in respect of the land mentioned therein.

It allows for schemes to be imposed and for subsidies to be paid relating to for example soil conservation works, the reparation of damage to the natural agricultural resources or soil conservation works which has been caused by a flood or any other disaster caused by natural forces; the reduction of the number of animals being kept on land in order to restrict the detrimental effect of a drought on that land; the restoration or reclamation of eroded, disturbed, denuded or damaged land.

GNR.1048 of 25 May 1984: is a regulation contains a number of provisions dealing with cultivation of virgin soil, cultivation of land with a slope, protection of cultivated land against erosion through the action of water, protection of cultivated land against erosion through the action of wind, prevention of waterlogging and salination of irrigated land , utilisation and protection of vleis, marshes, water sponges and water courses, regulating of the flow pattern of run-off water, utilisation and protection of veld, grazing capacity of veld, number of animals that may be kept on veld, prevention and control of veld fires, restoration and reclamation of eroded land, restoration and reclamation of disturbed or denuded land, declared weeds and invader plants, designation of biological control reserves.

Protected Areas

A number of different enactments provide for the protection from mining afforded to areas with special environmental features collectively referred to here as "Protected Areas". This legislation is relevant insofar as the Rehabilitation Guidelines are concerned only insofar as protected areas may be located within existing mining footprints or where new proposed coal mining is likely to impact on existing protected areas and specific measures need to be adopted to ensure that effective rehabilitation:

(a) Provisions barring mining in National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA)

(b) Protected areas preserved from mining identified through the MPRDA

(c) Protections afforded through the NEMA

(d) Various protected areas identified in NEMPAA – including Marine Protected Areas

(e) Protected areas because of heritage attributes - National Heritage Resources Act 25 of 1999 (NHRA) - Reference to impact assessment reports in the NHRA, Reference in the NHRA to mine dumps

(f) Protected areas identified through World Heritage Convention Act 49 of 1999 (WHCA) WHCA and exploitation of non-renewable natural resources, World Heritage Sites as protected areas

(g) Protected areas identified in provinces and in C plans also covered in EIA listing notice 3.

Appendix C: CONSIDERATIONS FOR FINAL LANDFORM, MODELLING, DRAINAGE AND SUSTAINABILITY

Shaping the topography

The general guideline is to regrade spoiled areas to approximate pre-mining contours and to ensure that the rehabilitated topography links seamlessly to the surrounding topography. However, a combination of factors such as mining method, type of earth-moving machinery and cost will determine the extent to which these ideals can be approached. Decisions taken at an early stage in the planning of a mine may impose constraints on later levelling operations so that, as far as existing mines are concerned, it may not be feasible to achieve this guideline without excessive expense.

The reconstructed surface may differ from the original in the following respects:

- In general angle, form and length of slopes are modified.
- Depending on stripping ratio and the volume expansion characteristics of overburden material, average elevation of the mined area will be lowered or raised.
- Spoil from the initial box cut forms an elevated ridge.
- A void remains after the final cut has been taken.
- Haulage ramps, depressed below the general level of the mined area, may persist.

Slope stability

Slope is one of the main parameters of erodibility and, as such, is of considerable importance in rehabilitation. Natural slopes and drainage patterns may be regarded as (quasi)equilibrium responses to the erosional forces of the particular environment and thus as relatively stable.

By altering them, a degree of instability will almost certainly be introduced and there will be a tendency for readjustment to take place by mass movement. This may take the form of rapid catastrophic failure (sliding, slumping) which occurs internally at some depth within the material, or more gradual erosion which is confined to the surface.

The former represents a safety hazard, is a feature of over-steep slopes, and can easily be remedied. The latter is more insidious and more difficult to prevent. Both will hamper successful rehabilitation.

Catastrophic failure

Sudden movement along a discrete failure surface occurs when the shearing resistance of the material and, more particularly, that of the foundation upon which it rests, is exceeded.

There are two mechanisms of failure: the sliding wedge type of failure (two intersecting rectilinear failure planes) which may occur when cohesionless fissile material (e.g. shale debris) is placed on a shallow foundation such as thin soil.

The other is rotational failure or slumping (failure plane rectilinear becoming arcuate; typical of deep, soft foundations). The angle of repose of dumped overburden spoil is in the region of 37o. Such material will normally not fail by shear unless failure occurs through the foundation.

The current practice of reducing outslopes of spoil dumped on level to gently sloping terrain to a gradient of at least 1v:3h (18,4o or 33%) makes them perfectly safe provided that the following precautions are observed:

- The foundation is stripped of soil (this is recommended in any event in order to provide topsoil for covering the outslope).
- Vertic, gley or any other materials containing high activity, smectite clays are avoided as foundations (information obtained from the soil survey).
- Over-steepening by undercutting of the toe of the slope is precluded.
- Vleis or poorly drained stream fringes should be strictly avoided as foundations.

Although 1v:3h is the maximum permissible gradient, other considerations suggest the strong desirability of lesser gradient to reduced erosion and permit mechanisation of revegetation and maintenance operations (agricultural tractors can be operated with most implements up to 20% (1v:5h) slope).

Erosion of slope

The three primary slope forms are concave, convex and rectilinear. The action of a bulldozer tends to produce convex or rectilinear slopes. On the other hand, in semi-arid to sub humid climates, natural slopes tend to be predominantly concave with pediments having characteristic angles usually between 0,5 and 5o (being least in desert areas and increasing with rainfall). From the drainage line upwards, the rate of increase in angle remains very low for the greater part of the length of the pediment, increasing in an exponential manner close to the upper limit of the slope. Reduction in slope angle in the direction of the toe of the pediment accommodates the increasing volume of rainfall runoff without undue erosion.

The following generalisations are probably valid (Schaefer, Elifrits and Barr, 1979):

- Concave slope form is most stable, is least affected by erosion, and yields the least amount of sediment to streams. Convex slopes erode most rapidly, yield most sediment and tend to change shape fastest. Rectilinear slopes are intermediate in behaviour, although long rectilinear slopes can be severely eroded in a single heavy rainstorm.
- Slopes on spoiled material will tend to develop concave profiles in their mid to lower sections over time. Therefore, if not shaped to this form initially, erosion will be aggravated.

Areas planned for rehabilitation to an arable standard must be graded to a slope (in %) which, multiplied by the erodibility factor (K) of the new soil, gives a product of 2.0 or less. A contour survey of the new topography should be carried out.

Large stones and boulders

These should as far as possible be buried below the final level of graded spoil so as to permit ripping and scarifying operations

Final high wall, void and access ramps

If it is not feasible to fill in the final void, then the high wall which remains, after mining is completed, should be graded or blasted to 1v:3h, or flatter from the surface down to the level of the permanent water table after rebound. The spoiled side of the void should be similarly graded to the base of the highwall and an area containing the highwall fenced off. The void may lend itself to wildlife or recreational purposes particularly if a water body can be formed. All slopes must be revegetated.

Several options exist as far as haul ramps are concerned. They would appear, in most cases, to have a minimal actual or potential utility except, possibly for discharging excess water from the mine area. Their catchments will normally be small unless considerable volumes of spoil are moved. Depending upon their elevation in relation to ground water levels, they may contain free water which could be linked to that in the final void to form a small lake system. At a minimum, their sides should be graded no steeper than 1v:3h.

Clearly, it is preferable to fill them as far as possible and slope the sides to produce a gentle swale in the topography. This can be achieved by leaving spoil in reserve on either side of the ramp for use at closure

Planning surface drainage

The eventual drainage pattern of a mined-out area will be a function of original topography, mining method and regrading strategy. It is difficult, but nevertheless important, to anticipate the permutations that may arise through variations in these three interrelated factors of which the last is amenable to the greatest degree of control.

In general, mine operators pay adequate attention to immediate problems of intercepting and diverting flow away from the working pit, haul roads and waste impoundment.

In recent years, more thought has been given to the progressive development of what must be a fully integrated and erosion-minimising drainage system for optimal disposal of surface water.

Without an overall drainage plan in mind, ad hoc regrading of increments of rehabilitated land may produce dislocations which will become apparent later. Problems generally arise from:

a) a tendency to produce a drainage density lower than that which existed previously, with fewer distinct drainage channels and convex rather than concave slope profiles. This will encourage erosion and it may be anticipated that, to re-establish equilibrium, rills and gullies will develop, erode headwards, and superimpose a new drainage pattern on the area. The guideline here is to regrade the distributed area to approximate pre-mining contours and drainage density (although not necessarily replicating the original pattern), to emphasise the formation of concave rather than convex slopes, or to introduce contour drainage structures which will intercept overland flow and reduce the length of slopes;

b) a tendency, particularly on relatively level terrain, to create an undulating topography with frequent blind hollows. Such "basin and ridge" topography will retard run-off but may, depending on rainfall, result in a mosaic of swampy areas and increase recharge of groundwater within the pit confines. Revegetation, water management, as well as future land utilisation and management may be prejudiced;

c) under-design of water disposal structures that are constructed in the early stages of mining if final discharge volumes are not anticipated.

The design of drainage systems should receive early attention from experienced conservation engineers and hydrologists in conjunction with an engineering approach to spoil disposal, taking consideration for the proposed final topography.

Designing with the final water balance in mind

As fuller understanding develops of the costs associated with managing water that has percolated though rehabilitated lands, surface drainage design has increasingly focused on ensuring that water landing on the rehabilitated surface drains off the mined land as quickly and as completely as possible, to minimise the quantities of in-pit water that have to be managed, and frequently desalinated, post-closure. Final voids could be sized to ensure that evapo-transpiration from the void's balances water "make", thus minimising seepage of affected waters from the mined area. Because evaporation is a water use in terms of the National Water Act, this needs to be authorized and permitted during the mine design/EIA stages.

Use of modelling to generate post-mining topography plans

Increasingly, mines are generating post-mining topography plans at very early stages in the development of mine plans using a range of computer modelling packages. These assist in preventing major dislocations, and also in ensuring that runoff from the final rehabilitated surface is maximised.

Appendix D: DETERMINING THE SOIL ERODIBILITY FACTOR (K)

The specification that the product of percent slope and soil erodibility factor (K) must not exceed 2.0 for land to be classed as arable (Appendix 3) represents a fairly stringent limit. Areas which meet this criterion (in addition to others specified in Appendix 3) will be truly sustainable arable land. Undoubtedly, there is much land which fails to meet these requirements, but which can be or is being safely cultivated. However, an erosion hazard exists, and conservation methods are required for protection.

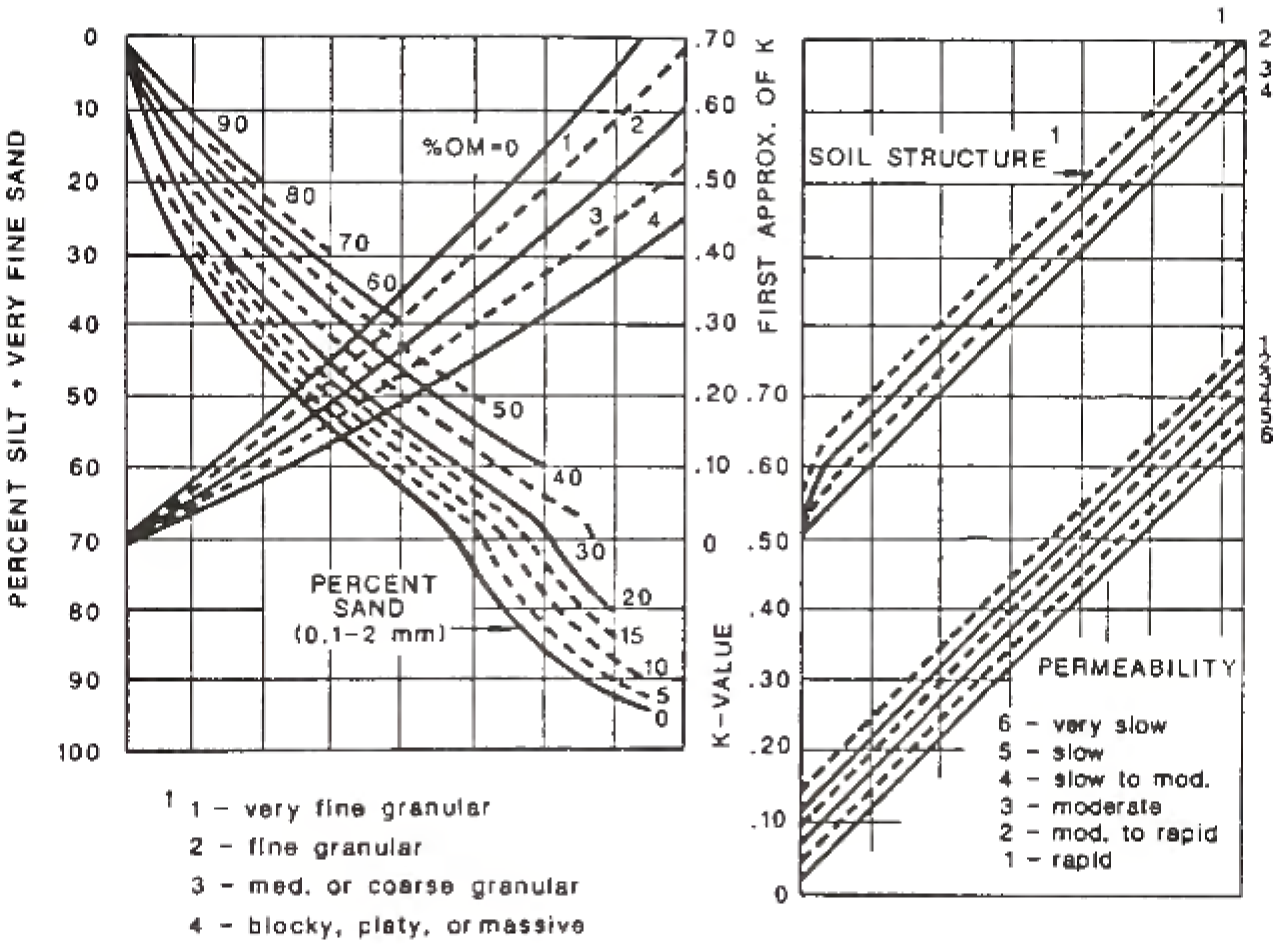
The nomograph (overleaf) uses the following five soil parameters, which have been shown by research to have a major effect in determining erodibility:

1. The mass percentage of the fraction between limiting diameters of 0.1 mm and 0.002 mm (very fine sand plus silt);
2. The mass percentage of the fraction between 0.1 mm and 2.0 mm diameter (residue of sand fraction);
3. Organic matter content obtained by multiplying the organic carbon content (g per 100g soil, Walkley-Black method) by a factor of 1.72;
4. A numerical index of soil structure; and
5. A numerical index of soil permeability (as indicated on the nomograph).

Different K values may often be found for various horizons of a soil, but that for the surface horizon is to be used. It should be noted, however, that the index of soil permeability (which is the most subjective of the five parameters) refers to the soil profile as a whole. For permeability, the controlling layer is often below the surface and the authors have given the following guide for codes 4, 5 and 6.

- Soils with a fragipan or cemented subsoil horizon are coded 6;
- Permeable surface soils underlain by massive clay or silty clay are coded 5;
- Moderately permeable topsoils overlying a silty clay or silty clay loam with weak blocky structure are coded 4, or 3 if subsoil structure is moderate or strong and texture is coarser than silty clay loam.

To use the nomograph, enter the left-hand scale with the silt plus very fine sand content and proceed to points representing the % sand, % organic matter, structure, and permeability in that sequence as illustrated by the dotted line on the nomograph. Interpolate between the plotted curves.



The soil erodibility nomograph (Wischmeier, Johnson and Cross, 1971)

Appendix E: LAND CAPABILITY CLASSIFICATION FOR MINED LAND[56]

Land performs many functions that are vital to society. Any particular area of land may be rated according to its relative or absolute capability vis-à-vis specified functions. This section assumes that the land is in agricultural use before mining commences and will revert to agricultural use after mining has been completed. In some cases, the end-use of disturbed land may be non-agricultural (e.g. for urban, industrial or transportation purposes, or for recreation or nature conservation). Such exceptional cases will need special treatment.

A detailed evaluation of agricultural capability is probably the most important component of the pre-mining land inventory because it provides the only objective basis for establishing the post-mining land use capability targets. It is not sufficient to state merely that land will be rehabilitated to an "agricultural capability". This is far too wide a concept and is susceptible to too many different interpretations for the term "capability" to be left unqualified. Similarly, in the undisturbed state, land capability may vary extremely widely, often over short distances, as a function of climate, soil characteristics, topography, surface and near-surface geology, and vegetation. Some classification of capability is therefore essential.

The system of land evaluation that is set out below has been designed specifically for surface mining in South Africa. It is not intended, and due to its simplicity is probably not appropriate, for use in non-mining situations, although it incorporates features of other systems, notably some of the criteria for identifying prime farmland developed by the soil conservation service of the United States Department of Agriculture.

Four land classes are recognised to accommodate all land. These are:

- Wetland
- Arable land
- Grazing land
- Wilderness land

The criteria for identifying each are presented in the form of an eliminating key. It must be emphasised that capability, and not present or past use, is the basis for allocating land to a particular category. Furthermore, assessment is an interpretive exercise using the raw data on soils and topography assembled during the pre-mining data collection period.

<u>Class I: Wetland</u>

Although all land performs hydrological functions, that termed Wetland is particularly important in regulating subsurface storage and drainage of excess precipitation on a continual rather than sporadic basis. It is made up of vleis, swamps, marshes, peatbogs and the like. There is usually a water table present at shallow depth in the soil with the result that it is difficult or impossible to recover soil material

[56] As defined in "Guidelines for the rehabilitation of land disturbed by surface coal mining in South Africa", COM, 1981

for later use because heavy machinery becomes bogged down, unless the soils are drained. Land assigned to Class I: Wetland, has one of the following characteristics:

- a diagnostic organic (O) horizon at the surface
- a horizon that is gleyed throughout more than 50 percent of its volume and is significantly thick, occurring within 75 cm of the surface.

Class II: Arable land

Land which conforms to all of the following requirements is designated as Class II: Arable: does not qualify as wetland.

- has soil that is readily permeable4 to the roots of common cultivated plants throughout a depth of 0.75 m from the surface
- has a soil pH value between 4,0 and 8,4
- has electrical conductivity of the saturation extract less than 400mS/m at 25oC and an exchangeable sodium percentage less than 15 through the upper
- 0,75 m of soil
- has a permeability of at least 1,5 mm per hour in the upper 0.5 m of soil
- has less than 10 percent by volume of rocks or pedocrete fragments larger than 100 mm in diameter in the upper 0,75 m of soil
- has a slope (in percent) and erodibility factor5 (K) such that their product is less than 2,0
- occurs under a climate regime which permits, from soils of similar texture and adequate effective depth (0,75 m), the economic attainment of yields of adapted agronomic or horticultural crops that are at least equal to the current national average for those crops, or
- is either currently being irrigated successfully or has been scheduled for irrigation by the DAFF.

Class III: Grazing land

Grazing land conforms to all of the following requirements:

- does not qualify as wetland or as arable land
- has soil or soil-like material, permeable to the roots of native plants, that is more than 0.25 m thick and contains less than 50 % by volume of rocks or pedocrete fragments larger than 100 mm diameter
- supports or is capable of supporting a stand of native or introduced grass species or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.

Diagnostic horizons and materials referred to in this discussion are as defined for the South African soil classification system (Macvicar *et al*, 1977).

Materials and diagnostic horizons which are not readily permeable and should therefore not be encountered within 0.75 m of the surface include:- hard rock, pedocretes (calcrete, ferricrete and silcrete) in sheet form, any soil material that is strongly cemented, dorbank, fragipans and diagnostic hard plinthic, gleycutanic and prismacutanic B horizons.

K may be obtained from the soil erodibility nomograph of Wischmeier, Johnson and Cross (1971), details of which appear in Appendix D.

Class IV: Wilderness land

This is land which has little or no agricultural capability by virtue of being too arid, too saline, too steep or too stony to support plants of economic value. Its uses lie in the fields of recreation and wildlife conservation. It does, however, also include watercourses, submerged land, built-up land and excavations. Wilderness land is defined by exclusion, namely:

- land which does not qualify as wetland, arable land or grazing land.

A land capability map of the area destined for disturbance must be made at a scale no smaller than 1:10,000. It is suggested that wetland be shown in blue, arable land in green, grazing land in yellow and wilderness land in brown. The hectarage in each of the four classes must be tabulated and expressed as a percentage of the total area.

Post-mining land use capability

Capability refers to the general kind and level of activity to which land is suited. Almost invariably, land will be in agricultural use or have a potential for agriculture prior to mining. The operator of a mine cannot be required to upgrade the original capability during rehabilitation. The operator should be expected to ensure that undue reduction of capability is not the result of the mining operation. Therefore, agricultural land capability prior to mining will be the primary criterion for determining the standard of rehabilitation to be attained in any particular instance. The land use capability assessment made prior to commencement of mining thus assumes fundamental importance in determining the rehabilitation plan.

The post-mining land capability standard uses pre-mining land capability as the starting point. In the final analysis, a mined-out area – less that occupied by spoil from the initial boxcut and by final voids – should have the same relative proportions of arable and grazing land as were present in the affected area before commencement of mining.

Currently, most prior wetland and wilderness land is rehabilitated to a wilderness standard, and the boxcut spoils to a grazing standard. However, due to increasing pressure, more effort is devoted to the rehabilitation of wetlands, especially pans and free- draining wetlands.

The original spatial distribution does not have to be replicated and may be improved on, for example, by engineering arable land into consolidated blocks where it might originally have occurred in a fragmented pattern.

The criteria for post mining arable, grazing, wilderness and wetland capabilities classes are as follows:

ARABLE: soil depth will exceed 0,6 m, the soil material must not be saline or sodic and the slope (%) will be such that when multiplied by the soil erodibility factor K, the product will not exceed 2,0 (see the soil erodibility nomograph in Appendix 8). In using the nomograph, a nominal value of 1% organic matter should be used)

GRAZING: soil depth will be at least 0,25 m

WILDERNESS: soil depth is less than 0,25 m but more than 0,15m.

WETLAND: depths as for grazing but use wetland soils which have been separately stockpiled

It is, of course, essential to compile, progressively, a post-mining land capability map showing the distribution of the three capability classes.

Appendix F: CONSIDERATIONS FOR SURFACE DRAINAGE STRUCTURE DESIGN

Surface drainage systems may require a variety of structures to control the flow of water. Among these are drains of various kinds, contour-bank canals, waterways lined with grass or other materials, berms, drop structures, energy dissipaters and sedimentation ponds.

These structures should be designed and constructed according to conventional engineering practice and will not be elaborated on here. Contour-bank canals, grassed waterways and toe berms merit special discussion in the context of the rehabilitation of disturbed land.

Bearing in mind the propensity for rehabilitated lands to undergo differential subsidence, and the problems that this causes with respect to the sustainability of the contour banks, it is usually best to ensure the survival of these banks by increasing the within-contour slope to 1 to 2%. This may increase the scouring effect within the contour channel but will greatly decrease the possibility of the contour banks overtopping and causing severe erosion.

Contour systems and grassed waterways

These are anti-erosion measures designed to shorten the hydraulic length of slopes by intercepting overland flow (contour structure) and to conduct the latter to a safe discharge point (waterways). It should be emphasised that the two are complementary and that waterways must be provided if contour bank are installed. The following general design procedures and standards are proposed with the recommendation, however, that any system which has not been professionally designed should be subjected to competent review by an agricultural engineer before being implemented.

Establish the vertical interval of spacing between canals

This first step in design should be based on the nominated soil loss that can be tolerated. Soil loss is a function of the kinetic energy of the prevailing rainfall, grade of slopes, erodibility of the particular soil and anticipated plant cover. In view of the extreme importance of topsoil on rehabilitated land and the expense of providing it, the aim should be to contain soil loss to a minimum. A conservative annual loss of less than 10 tonnes ha-1 would seem to be appropriate.

Tables are available[57] for obtaining appropriate canal spacing from input values for the following variables:

- Nominated soil loss;
- Rainfall energy;
- Slope;

[57] Soil loss estimator for Southern Africa. Natal Agricultural Research Bulletin No. 7, 1976. Obtainable from the Director, Natal Region, Department of Agriculture and Fisheries, Private Bag X9059, Pietermaritzburg 3200, South Africa.

- Soil erodibility index; and
- Percent cover.

Soil erodibility values of mine soils for use with the tables should be arrived at as follows:

- Starting with a value of 4,5
- Add -0,5 if clay content of topsoil is less than 15% or +0,5 if greater than 35%
- Add -0,5 if topsoil depth is between 25 and 50 cm or -1,0 if less than 25 cm
- The cover percentage may be taken as:
  - 80% for sod-type grasses;
  - 70% for tufted grasses where annual rainfall exceeds 700 m; and
  - 60% for tufted grasses where annual rainfall exceeds 700 mm.

Determine the size of channel by solving the equation A=Q/V

By deriving the values Q = runoff intensity (m3 sec-1) for the catchment of contour-bank canal and V= the average velocity of water flowing in the canal (m sec) for the type of channel planned, the equation can be solved for "A", which is the required cross sectional area of the channel.

Runoff intensity, Q

Since the ground slope distance between canals is known and the canal length can be determined, the area of the catchments served by each canal can be calculated. Note that canal length should not exceed 600 metres for good conditions and 400 metres for poor conditions. Since one will usually be dealing with small catchments, the modified USLE soil conservation service procedure may be used to determine runoff. A publication7[58] by the Division of Agricultural Engineering of the Department of Agriculture and Fisheries contains details of this procedure including a map showing maximum 24-hour rainfall intensities for South Africa and a series of graphs for determining Q. One of the parameters used is a so-called "curve number", determined by soil type and ground cover. It is recommended that a curve number of 85 be used for mined land that is bare of vegetation, if topsoil depth is more than 50 cm, and clay content is greater than 15%. If either or both of these conditions are not met, then use the maximum curve number of 90.

[58] "Die beraming van afloopintensiteit" (Eerste uitgawe, geldig tot 1981–07-01). Available from the Division of Agricultural Engineering, Private Bag X515, Silverton, 0127, RSA.

Velocity of flow in the canal, V

This is related to the hydraulic radius of the channel (R), its hydraulic gradient (S) and a coefficient of roughness (n), by Manning's equation:

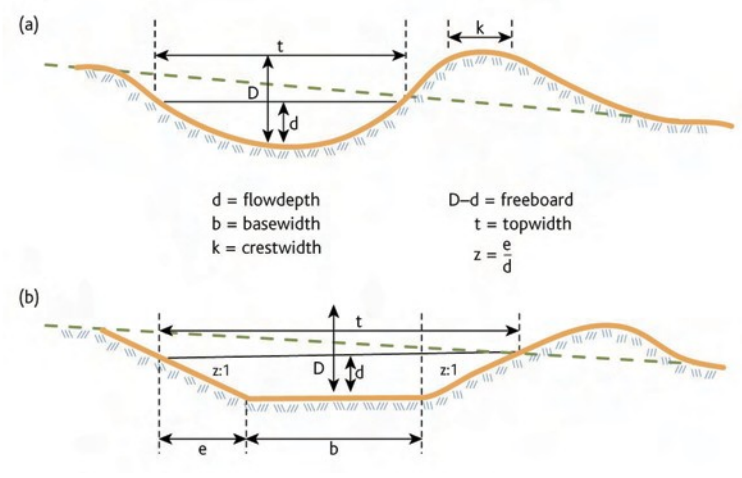
$$V = \frac{R.S^{0,5}}{n} \text{ m sec}^{-1}$$

The maximum permissible velocity must be non-scouring and standard limiting values for V exist for various soil and basal cover conditions (see, for example, Contour bank systems design data, Dept of Agriculture and Fisheries, Undated). V is thus selected as is S (0,2 to 0,4% for contour bank canals but may be steeper for broader structures such as waterways). Values for Manning's n corresponding to various channel conditions are widely available (e.g. Beasley, 1972, Han and Barrie, 1978). The hydraulic radius R can thus be found from Manning's equation. Since the cross-sectional area of the canal can be found from A=Q/V and R is known, various combinations of depth and width can be calculated, or derived from nomographs (e.g. Beasley, 1972). Dimension will depend on the cross-sectional shape or type of channel.

Tables and nomographs which solve A = Q/V and Manning's equation simultaneously have been prepared and these may be used to arrive directly at dimensions. "Contour- bank systems design data" may be consulted for canals of low gradient, and Green (1980) for larger waterways.

<u>Cross-sectional shape</u>

The following diagram illustrates two typical cross-sectional shapes and gives the dimensional inter-relationships of each. An approximately parabolic section is recommended for narrower cross-slope channels whereas larger and steeper structures, such as waterways, should have a trapezoidal or rectangular shape.



	Cross-sectional area (a)	Wetted perimeter (P)	Hydraulic Radius $R = \frac{a}{P}$	Top width (t)
(a) Parabolic	$\frac{2}{3}td$	$t + \frac{8d^2}{3t}$	$\sim \frac{2d}{3}$	$\frac{a}{0,67d}$

Properties of:
(a) parabolic and
(b) trapezoidal channels

Safety factor

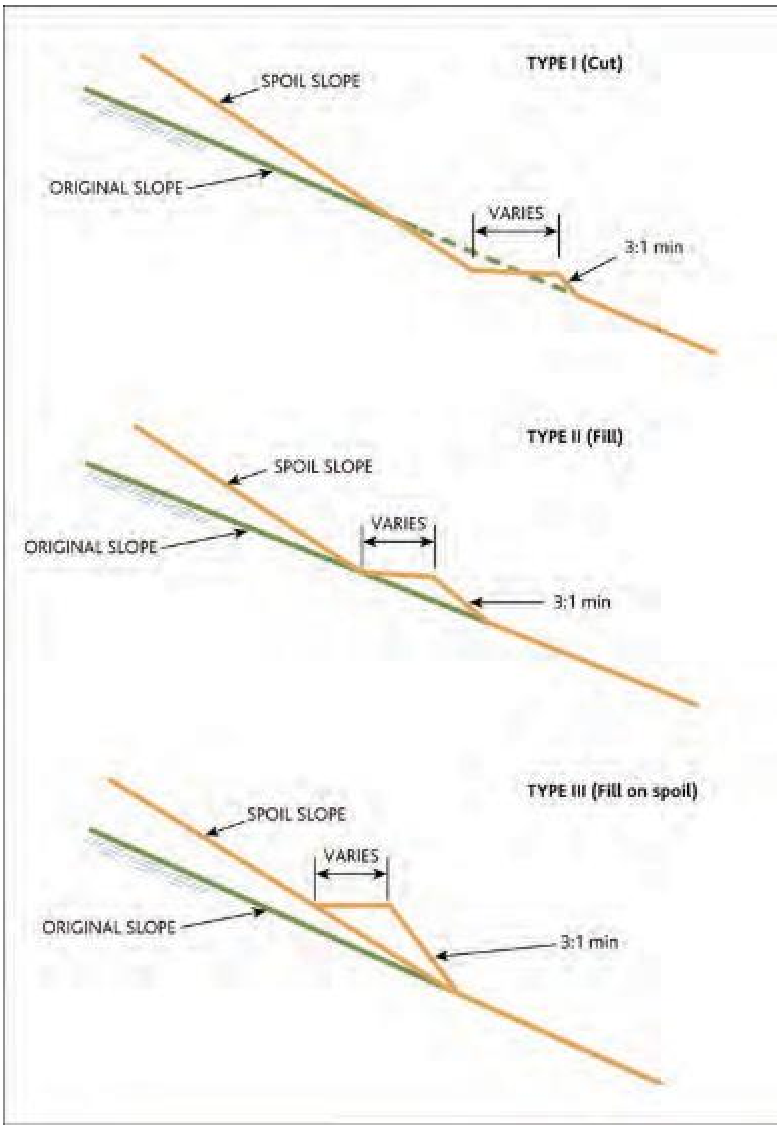
Differential subsidence of spoiled material poses a threat to contour structures. Consequently, they should be over-designed to give a larger safety factor than is normally allowed. Care should be taken to compact the material that is used to provide freeboard prior to covering with soil and grassing. Structures should be inspected regularly and modified or reinforced, where necessary, to avoid breaching.

Grassing

Under Highveld conditions, a range of grasses provide quick cover and superior erosion control. Those recommended are *Digitaria decumbens* (pongola or lowveld finger grass), *Pennisetum clandestinum* (Kikuyu, seeded), *Chloris gayana* (Rhodes grass, seeded) and *Cynodon dactylon* (Kweek, Puerto Rico, seeded). Adequate fertiliser must be applied at planting and maintenance dressings given annually

Toe berm

This is a berm or bench of compacted and vegetated soil constructed at the toe of the outer slope for the purpose of reducing the velocity of run-off and trapping sediment (see next diagram).



Sections illustrating toe berm construction

(Reclamation Manual for Coal Surface Mining, State of Virginia, USA)

It is useful to control excessive erosion until the slope has been stabilised by vegetation. The width of the berm should be 1 m for every 10 m of slope length. The bench section of the berm should be sloped a minimum of 1% and maximum of 3% away from the slope and its outer slope should be 1v:2h or flatter. It should be compacted and vegetated immediately.

Appendix G: EXAMPLE OF A PRE-MINING SOIL SURVEY, AND SOIL STRIPPING AND HANDLING PLAN

Detailed soil surveys should be done in all cases where the mining activity or infrastructure development will result in significant soil disturbance. This is both to determine land capability, so as to provide a logical target for post-mining land capability, and also to define the materials that will be available for rehabilitation. The information derived from the soil survey is usually also used to define pre-mining land capability and the field inspection is used as an opportunity to determine pre-mining land use, as both factors are required for completion a site's EIA/EMP documentation.

Scope of work for soil surveys and reporting

- The survey should be done on a 100 m grid for pits <100 ha (or for areas to be disturbed for waste rock dumps, tailings dams, or surface infrastructure, e.g. shafts, haul roads, etc).This may be increased to a 150 m grid on larger pits, provided the soil variability is such that this increased spacing does not significantly downgrade the usefulness of the final report. (Required grid is always specified when asking for quotes).
- The survey should include a 100 m or 150 m "fringe" around the footprint of the pit (to cater for outsloping of box cut spoils etc.). Where the survey is done on 100 x 100 m grid, a narrower fringe (100 m) is used. The larger fringe distance is used with the larger grid spacing.
- For underground mines where surface impacts could manifest, a "reconnaissance" type soil survey should be done with a 250 x 250 m grid being applied.
- A representative soil profile pit should be excavated for each major soil type identified. The pits should be photographed, and the usable soil horizon/s should be sampled for physical (texture & bulk density) and chemical analysis (pH, resistance, Ca, Mg, Na, P, K, and organic matter content). All results should be properly documented.
- The data obtained should be processed to provide detailed plans showing soil mapping units, with usable soil depths (the soil stripping plan), and with land capability classes.
- Land capability classes, as defined in Appendix E, should be determined and mapped.
- Present land use must be assessed and mapped during the field assessment. From the information gathered comment should be made on existing soil erosion and evidence of land misuse such as alien invasive plant infestation.

Deliverables

The survey deliverables should include:

- A comprehensive report that includes:
  - A table showing all soil forms in the survey area, their aerial extent, and the volume of each soil type that is available for stripping; and

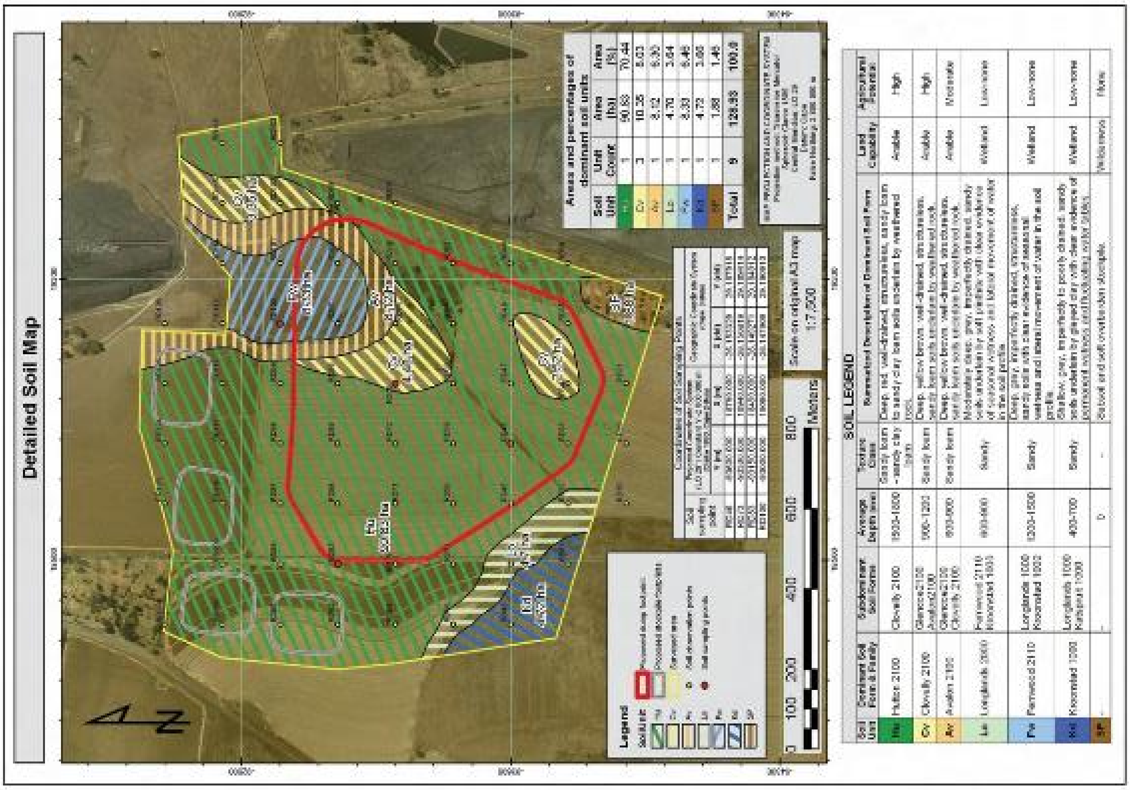
- Comment on the erodibility of the different soil types.

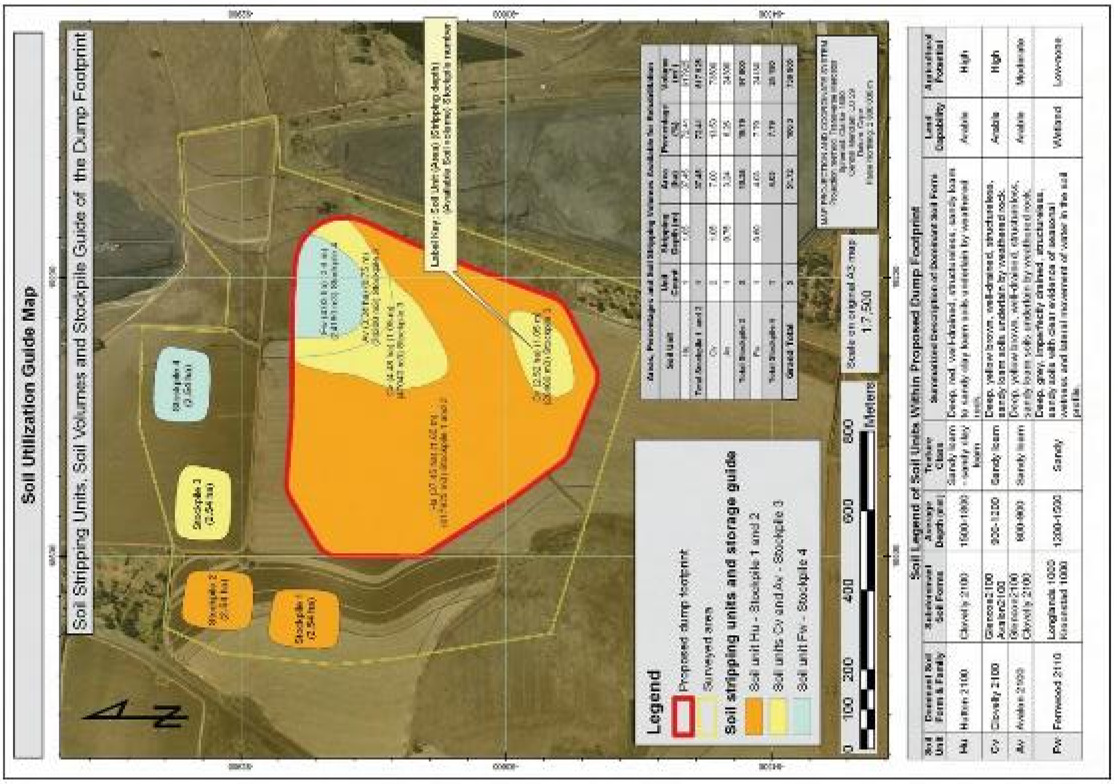
- The following maps:
  - Map 1: Soil mapping units (soil types);
  - Map 2: Stripping plan showing areas of uniform "usable soil" depth – areas differentiated at 10 cm soil depth intervals (include a table showing areas and volumes of soils to be stripped in each depth class);
  - Map 3: Land capability units as defined in Appendix E of these Guidelines; and
  - Map 4: Present land use.

Soil surveys can be done at any time of the year but should preferably be done from April to September when conditions are drier and areas are easily accessible.

Typical examples of the required maps are provided on the following pages.


Land Capability Map
Scale on original A3 map 1:7 500
0 100 200 400 600 800
Meters
Legend
Proposed dump footprint
Proposed topsoil stockpile footprints
Surveyed area
Land Capability
Arable (Soil units Hu, Cv and Av)
Wetland (Soil units Lo, Fw and Kd)
Wilderness (Soil unit SP)
Areas and Percentages of Land Capability Classes
Land Capability Class | Soil Unit | Unit Count | Area (ha) | Area (%)
Arable | Hu, Cv, Av | 1 | 109.31 | 84.78
Grazing | None | 0 | 0.00 | 0.00
Wetland | Lo, Fw, Kd | 2 | 17.75 | 13.77
Wilderness | SP | 1 | 1.88 | 1.46
Total | | 4 | 128.94 | 100.0


Detailed Soil Map
Scale on original A3 map 1:7 500
0 100 200 400 600 800
Meters
SOIL LEGEND


Soil Utilization Guide Map
Soil Stripping Units, Soil Volumes and Stockpile Guide of the Dump Footprint
Legend
Proposed dump footprint
Surveyed area
Soil stripping units and storage guide
Soil unit Hu - Stockpile 1 and 2
Soil units Cv and Av - Stockpile 3
Soil unit Fw - Stockpile 4
0 100 200 400 600 800
Meters
Soil Legend of Soil Units Within Proposed Dump Footprint


Current Land Use Map
Legend
Surveyed area
Current Land Use
Maize
Fallow land - Maize
Grazing
Vacant - occasional grazing
Stockpile - subsoil
Areas and Percentages of Current Land Uses
0 75 150 300 450 600
Meters

Appendix H: SAMPLING FOR SOIL ANALYSIS (POST-PLACEMENT ASSESSMENT)

In the case of rehabilitated land, there is likely to be greater heterogeneity of a more random short-range nature than occurs in nature. As it is not practical to vary fertiliser application rate to meet short-range variations in nutrient requirements, recommendations must aim at satisfying some average requirement for the rehabilitated field. In most cases, land has been top-soiled with mixtures of top- and sub-soils and, accordingly, soil fertility levels are usually low.

Sampling procedure

Initial sampling after rehabilitation

The following procedure is recommended:

- The area to be sampled must first be assessed for its uniformity. If there are obvious differences in replaced soil type, slope or plant growth, the field should be split up into uniform sampling units.
- Draw one composite topsoil sample made up from at least 20 sub-samples taken at random points within the uniform area selected. Obvious atypical situations (e.g. local depressions and drainage lines) should be avoided.
- Sampling depth should be 0-150 mm for the initial fertility survey after topsoiling and prior to establishment of vegetation.
- Sub-samples are most conveniently taken by means of a Beater sampler, bulked, thoroughly mixed after breaking up clods, spread thinly on clean paper or plastic sheeting and portions scooped representatively for the whole area into a plastic bag, sufficient to give at least 500 g of composite sample.
- This should be appropriately labelled with reference to a sampling plan and submitted for analysis.

Sampling in the second and subsequent years after rehabilitation

After the initial fertilisation and plant establishment year, it is frequently possible to amalgamate sampling units that show similarities in fertility analysis.

- Sample unit size should not exceed 20 ha, and samples should be made up of at least 20 sub-samples for each field or uniform part of a field.
- For monitoring purposes under a grass cover, sample to a depth of 100 mm (revert to 150 mm if and when annual cropping is commenced).
- Sub-samples are most conveniently taken by means of a Beater sampler, bulked, thoroughly mixed after breaking up clods, spread thinly on clean paper or plastic sheeting and portions scooped representatively for the whole area into a plastic bag, sufficient to give at least 500 g of composite sample.
- This should be appropriately labelled with reference to a sampling plan and submitted for analysis.

Frequency and timing

Initial topsoil samples must be taken after levelling and prior to the application of basal fertiliser and lime. Thereafter it is recommended that sampling and analysis be carried out annually until the requisite P and K status has been built up. Once the desired nutritional status has been achieved, intervals of three to four years can be allowed between sampling. Naturally, if growth problems should develop that are not attributable to some obvious cause, ad hoc sampling and analysis is necessary. It is also recommended that the spoil material immediately below the topsoil be sampled for analysis of exchangeable acidity and potassium once the vegetation has become well-established (say in the third year). A single sample (not composite) per 20 ha should suffice for diagnostic purposes.

Sampling should always be carried out at the same time of the year. For soils under pasture, the best period is between March and June, at least six weeks after the last fertiliser application.

Appendix I: SOIL COMPACTION AND ITS ALLEVIATION

Soil compaction is a major factor limiting post-rehabilitation land capability in the South African mining industry. In the Mpumalanga coalfields, for example, approximately 40,000ha of land have been rehabilitated, and surveys conducted on these lands indicate that the great majority have bulk densities that severely restrict plant rooting. It is clear that the currently used technology to loosen soils after rehabilitation is unsatisfactory, and an industry-sponsored research initiative is currently investigating alternative methods of compaction alleviation.

Causes of compaction

Soil compaction is caused by the techniques and equipment used in the stripping, transport, stockpiling and replacement of soil materials during the mining and rehabilitation processes. Additional compaction occurs during the levelling of the replaced soil and during its preparation for planting.

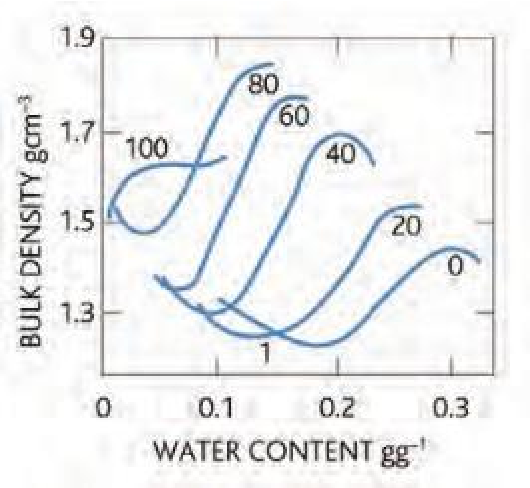
Apart from compaction of the replaced soil, compaction also occurs in the overburden materials that are handled and thus disturbed during the mining process. During disturbance, overburden expands in volume. This is then followed by a degree of natural recompaction as the material slowly settles. The degree of this recompaction is variable, leaving an overburden material with zones of differing bulk density and porosity, which become susceptible to differential settlement over the long term. Compaction frequently occurs at the overburden surface because of the heavy machinery that is used for the grading of the spoils materials. The soil/spoil interface is consequently a major barrier to root (and water) penetration.

Factors affecting the compaction of materials

Rigorous quantitative relationships that can be applied universally to predict the behaviour of loose materials when subjected to loading do not exist. Nevertheless, the following qualitative relationships are well known and may be used to guide rehabilitation practice.

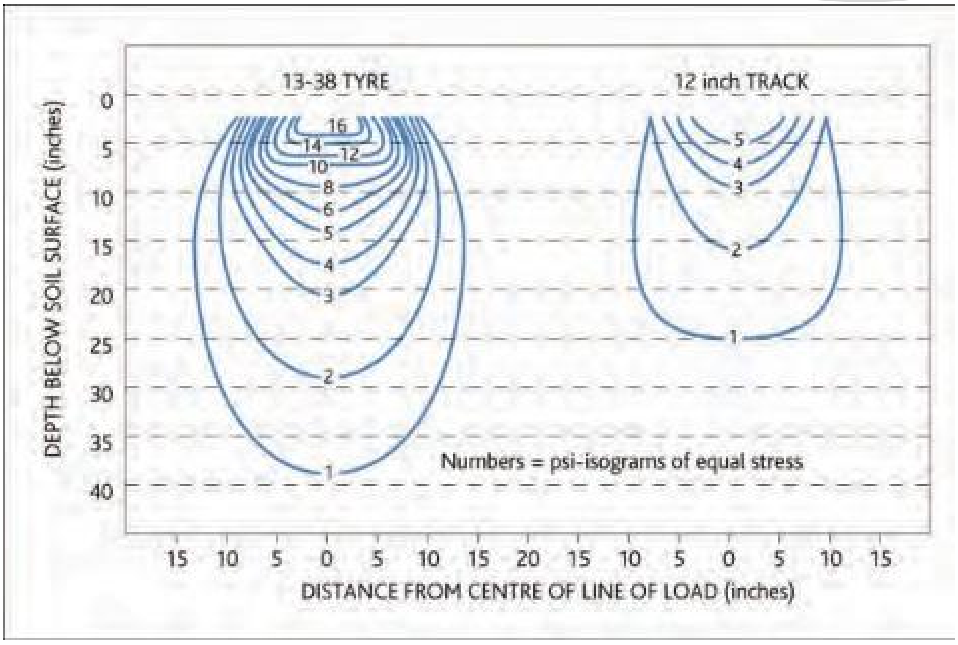
1. Compactibility varies with particle size distribution. Sandy materials other than pure sands, and particularly those having a high proportion of fine sand (0,2-0,02 mm diameter), are most susceptible to compaction and the formation of high bulk densities. A reliable indication of the comparative susceptibility of soil and other finely divided materials to compact under loading may thus be obtained from particle size analysis.

2. In general, for a given material and external load, the resulting bulk density yields an S-shaped curve when plotted against moisture content (see diagram). Moisture contents for both minimum and maximum bulk densities are not fixed values for all materials and thus need to be determined in each individual case. In order to avoid excessive compaction (or achieve a high degree of compaction where this is required) it is clearly important, especially in susceptible materials, to determine the optimum moisture content and operate at or near to this value. In In the context of topsoiling, however, this implies a seasonal operation which would rarely be a practical possibility. Consequently, a greater degree of compaction may be expected in areas topsoiled during the wet summer months, so plan to strip and replace soils in the drier winter months (except in the Western Cape province).



Effect of water content on the compaction of mixtures of fine sand and a silty clay. Percentages of fine sand are shown. (Taken from Marshall and Holmes, 1979)

3. Clay particles tend to take up preferred parallel orientation under pressure, the effect increasing with moisture content. This results in a decrease of shear strength. Low- activity clays orientate more readily than high-activity clays due to their smaller interparticle forces.
4. Since the mineralogy, as well as texture, of a material influences its compactibility, it is predictable that sandy kaolinitic soils (e.g. the high sand series of Hutton, Bainsvlei, Griffin, Avalon and Clovelly forms) will be more susceptible to compaction and associated problems.
5. There is some evidence that gleyed materials are highly compactible.
6. Due to point loading and slip, wheeled vehicles cause greater stresses at comparable depths than do tracked vehicles (see diagram) and it is obviously preferable to use the latter wherever the option exists.
7. By increasing vehicle speed, the duration of stress is reduced and total compacting force is thus lessened.



Equal vertical stress lines perpendicular to the direction of travel for an equally loaded tyre and track. (Marshall and Holmes, 1979)

Problems caused by compaction

Differential subsidence

An initially well-graded surface may subside differentially due to the presence of relatively under-compacted zones in the spoil. The effect of differential subsidence is to downgrade the standard of rehabilitation in two ways:

- Localised hollows ("melon holes") may become wet spots which cause management problems irrespective of whether the land is destined for grazing or arable use. In extreme cases, sinkholes may develop in the rehabilitated topography.
- Subsidence on sloping topography will cause failure of anti-erosion structures such as banks and furrows that have been aligned according to immediate post-levelling contours. This will lead to aggravated rill and gully erosion at points of failure.

In practice, differential subsidence is unavoidable. Remedial measures consist of levelling hollows using additional soil material, and over-designing surface water interception structures.

Drainage impedance

Saturated flow of moisture through soil varies with porosity and thus inversely with bulk density. An increase in bulk density not only reduces total porosity but usually also shifts the pore size distribution in the direction of a smaller average pore size. Because flow rate of water through soil decreases as the fourth power of pore radius (i.e. halving pore size decreases flow rate by a factor of 16), compaction at the soil/spoil interface or at any other shallow depth can have a profound effect on internal drainage and thus on plant growth and land use.

The consequence of having a compacted layer near the surface which underlies a more permeable layer is as follows:

- The limit to the rate of flow of water through the profile as whole is imposed by the least permeable layer.
- As soon as water infiltrates at the surface faster than it can be conducted through a less permeable layer, it starts accumulating at the contact between the two layers. This water may discharge in a lateral direction by sub-surface flow to accumulate in topographic lows, including “melon holes” and other surface irregularities, with the resulting problem of wet or marshy spots. On the other hand, on relatively level topography where lateral discharge is slow, a seasonally fluctuating, perched water table may develop. This will provide a barrier to root development, thus reducing even further the effective depth of soil. The perched water table may even reach the surface and discharge by overland flow with an attendant erosion hazard.
- Therefore, possible hydrological effects of over-compaction at shallow depth include drowning of bottomlands and depressions, killing of roots by a rising water table, restricted soil depth available for rooting, and heightened flood and erosion hazards.

<u>Root impedance</u>

It has already been pointed out that compaction decreases the proportion of larger pores. It is usually also accompanied by an increase in soil strength. Large pores function in aeration and root penetration, i.e. roots are dependent on large pores for their oxygen supply and will only elongate if large pores are present or if soil strength is sufficiently low to allow active displacement of soil by root pressure. Therefore, compaction has both a mechanical and physiological effect on rooting to the extent that the latter is progressively inhibited and eventually prevented by increasing bulk density. Unfortunately, it is not possible to specify a critical upper limit of bulk density applicable to all materials. The effect of bulk density on plant growth is progressive, varies with the type of plant being considered and is modified by soil characteristics such as particle size distribution, soil strength and type of clay mineral. However, as a very general guide, roots will fail to penetrate materials compacted to bulk densities of greater than about 1,500 kg m -3 for clays (>35% clay) and about 1,700 kg m -3 for sands (<15% clay). These and intermediate values for intermediate clay percentages should not be exceeded within the top 1 m of soil or spoil.

<u>Alleviation of compaction</u>

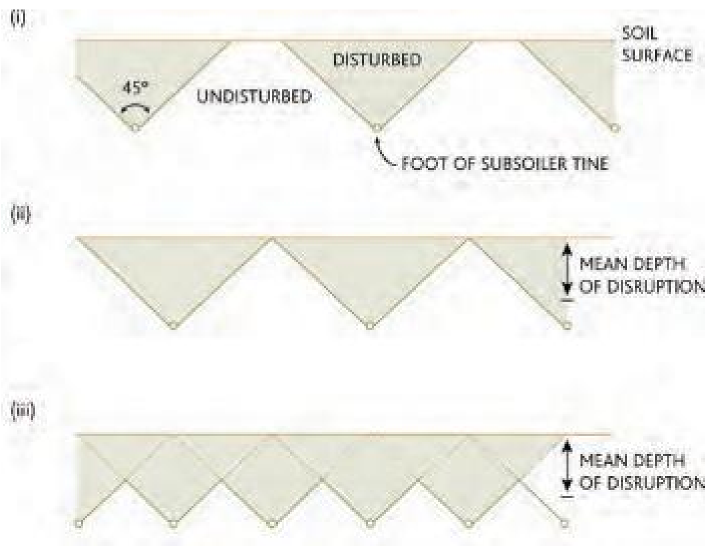
Prevention is better than cure. However, the rehabilitation techniques currently in use in the South African mining industry have been singularly unsuccessful in preventing compaction of rehabilitated profiles. General guidelines for the minimisation of compaction are contained in the body of the guidelines. This Appendix focuses on methods of amelioration of the compaction once created. The principal focus is on the use of tillage as this has been proven to be effective internationally; however, brief mention is made of the potential for use of ameliorants and biological agents.

Disruption of compacted layers by deep tillage

As compaction in the surface layers is largely unavoidable (although it can be minimised by planning vehicle routes to reduce the extent of overpass and by working in the drier months) and has such serious implications for successful revegetation and future land use, ripping or subsoiling becomes more or less mandatory. This operation should be carried out as a matter of routine, unless it can be shown conclusively that bulk densities do not approach critical limits anywhere in the topsoil or at the soil/spoil contact. The efficiency of ripping/subsoiling tends to be highly variable in practice, however, and care should be taken to ensure that it has the desired disruptive effect. In this connection, the following observations may be helpful:

1. Successful subsoiling depends on shattering the compacted material. Wet soils will deform plastically without shattering. Moisture content at the time of subsoiling should therefore be low, preferably nearer to the permanent wilting percentage than to the field moisture capacity. In practice, this means that subsoiling will be a seasonal operation, confined to the dry months of the year.
2. When a subsoiler tine is drawn through a material, the cross-sectional area of disturbance, viewed along the axis of travel, is a V with its apex at or close to the point of the subsoiler. The break-out angle of each arm of the V from the vertical has a maximum (and common) value of 45º (see diagram). Depending upon the depth to which the subsoiler point is inserted and the distance between adjacent tine paths, the Vs will:
   i. not intersect;
   ii. intersect at the surface; or
   iii. intersect below the surface to form a sawtooth profile above which overlap of the disturbed zones occurs.

   Mean depth of soil disturbance for a break-out angle of 45o is the vertical distance from the soil surface to a parallel plane through half amplitude of the sawtooth profile. Mean depth of soil disturbance is thus always less than subsoiler depth.



Zones of subsoiler disturbance resulting from different tine path spacings (viewed end-on to direction of travel) (COM Guidelines, 1981 surface coal mining)

3. Subsoiler depth and tine path spacing will be determined by:
    i. the depth of the compacted layer which is to be disrupted;
    ii. the desired degree of disruption; and
    iii. the actual break-out angle achieved.

    If the latter is 45º, then for any particular compacted layer a suitable subsoiler depth tine spacing combination can be arrived at by plotting the sawtooth profiles resulting from several feasible subsoiler depth-tine spacing combinations on a chart as illustrated in this diagram. Should the break-out angle be less than 45o, an appropriate adjustment to either depth or tine spacing should be made. It must be emphasised that the procedure outlined above should be used only to arrive at a first approximation of subsoiler setting; the actual subsoiling effect should be checked in trenches dug at 90º to the path of the subsoiler.
4. In practice, compaction may be expected usually in the immediate vicinity of the soil/spoil contact and the subsoiler point should, therefore, be put in below this contact wherever possible (large stones and boulders in the spoil may preclude this). Disturbance of the contact and some mixing of soil and spoil are important for keying the soil to the spoil and establishing hydraulic continuity between the two.

<u>Recompaction and the need for re-ripping</u>

There is some evidence that, despite soils having been ripped, the soils resettle and remain excessively compact. Monitoring of soil strength and bulk density should be used to confirm the existence of this phenomenon, which may be related to soil "memory" and the destruction of micro-aggregate structures during the soil handling processes. There is no certainty, however, that the phenomenon is not simply due to ineffective ripping in the first place. In any event, the problem should probably be dealt with by the inclusion of organic matter into the profile and the encouragement of soil biota to re-establish soil structure and porosity, in addition to the physical ripping process.

<u>Use of chemical and organic amendments</u>

Most replaced soil in South African rehabilitated land is a mixture of top and sub-surface horizons, which consequently has a lower organic matter content than normal topsoil. Soils treated with organic amendments, such as biosolids, compost, sawdust etc generally have greater resilience and resistance to compaction. The problem lies in the development of practical methodologies for the application and incorporation of such amendments. Such equipment has not yet been developed for use in South Africa.

Chemical ameliorants such as phospho-gypsum have been used to reduce surface crusting, and a number of ameliorants (humic products, polyacrylamide, for example) are known to stabilise soil aggregates. They are not known for their ability to ameliorate existing compaction.

Plant root abilities to penetrate compact soils

Certain plant species are reported to be more tolerant of high bulk densities than others. Of the legumes in common use in South Africa, soybeans, cowpeas and vetch are reportedly more tolerant, while of the grasses, *Cynodon dactylon* and *Paspalum notatum* possess dense rooting systems capable of penetrating compact subsoils. In addition, Vetiver grass (Vetiveria zizanioides), and Napier fodder (*Pennisetum purpureum*) produce dense rooting systems with a greater than average ability to penetrate compact soils.

While these species may prove beneficial in cases of marginal compaction, there is little doubt that for the most compact soils, physical loosening by appropriate tillage to the correct depth is the only solution.

The effect of fauna or micro-fauna

Termite burrows in extremely compact soil

Termite mounds on rehabilitated land (~10 years old)

Various burrowing animals have been observed to loosen the surface horizons of soil, but their activities do not extend on any significant scale to the subsoil. While earthworms may play a significant role in the moister temperate parts of the world, there is no evidence of them doing so in South Africa. A case could be made, however, for bioperturbation by termites, as tunnels have been observed penetrating through highly compact soil materials, and the numbers of termitaria have been observed to be increasing on many mature rehabilitated profiles in Mpumalanga. Progress, however, would be exceedingly slow, and there is no current replacement for the requirement to loosen compact replaced growth media using deep physical tillage.

Appendix J: CONSIDERATIONS FOR SOIL FERTILISATION AND LIMING

Management of soil fertility is an important aspect of revegetation for the following reasons:

- Rapid establishment of a vigorous plant cover should never be prejudiced by avoidable deficiencies or imbalances of plant nutrients; disorders must be detected and rectified at the outset;
- As many South African mining areas have infertile, acid soils, it follows that topsoiling materials will often. although not always, require extensive amelioration;
- Because of mixing of soil horizons and substrata, and possible contamination by acid –producing pyrite from spoil and waste, materials used for topsoiling will have nutrient and acidity levels that are far more unpredictable than natural soils;
- Amelioration of subsoil acidity (often a serious agricultural problem in Highveld areas) is difficult and expensive under normal circumstances. An opportunity exists for incorporating lime throughout the rooting depth during topsoil spreading.

Fertiliser requirements are dictated by several considerations, the most important of which are:

- the type of vegetative cover or crop to be grown;
- its manner of utilisation (ranging from complete removal to use on the land by animals);
- the production level or yield target that may be set taking into account soil and climatic potential; and
- the nutrient status of the soil.

Despite some limitations, conventional soil analysis (soil testing) provides the best guide to the latter and a sound monitoring programme is regarded as essential for proper rehabilitation. In any fertilisation programme, a distinction must be made between basal application of fertiliser and lime designed to correct disorders and raise the fertility status to a suitable level prior to vegetation establishment, and maintenance dressings applied for the purpose of making good losses and keeping up nutrient levels. This distinction is especially relevant to rehabilitation of disturbed land where the initial deficit is likely to be greater than on comparable undisturbed agricultural lands. Sampling procedures and methods for monitoring soil fertility are to be found in Appendix 9.

Lime

Determining application rate

In normal agricultural practice, three factors determine the amount of lime required to ameliorate soil acidity in any particular situation. These are:

- the degree of soil acidity;
- the acid tolerance of the crop to be grown (varies widely between species); and
- the neutralising ability of the liming material to be used.

The first factor is most conveniently measured as exchangeable acidity. The second factor is considered by specifying the extent to which exchangeable acidity must be reduced for the particular crop in question. It is usually recommended that for all grasses, excluding *E. curvula*, exchangeable acidity should be reduced to a level at which it is equivalent to 50% of total exchangeable cations. The corresponding upper limit for temperate legumes is 25% although for *Trifolium spp* 5-10% is probably safer. Lucerne reputedly requires a value of 1% (i.e. virtually complete neutralisation of exchangeable acidity), although there are examples of successful establishment and survival of Lucerne in soils with greater levels of acidity than this.

Although liming is not normally recommended for *E. curvula* or for tropical legumes, the former, at least, has been known to show a response. In view of this and the desirability of stimulating an active microflora to aid in the development of stable soil aggregates (neutral pH is optimum in this regard), it is recommended that soil be treated in the same way for *E. curvula* as other grasses and limed to 50% acid saturation.

It is further recommended that, where land is being rehabilitated to an arable standard, all topsoil replaced be limed to 1% acid saturation. Lime requirement must be carefully assessed from laboratory determinations of exchangeable acidity and exchangeable cations in order to preclude under- or over-liming. Over-liming can induce deficiencies in certain essential minor elements. Actual application rate must consider the neutralising equivalent (relative to CaCO3 = 100) of the liming material used.

Dolomitic rather than calcitic lime should be employed to provide magnesium (in addition to calcium) wherever the value for exchangeable magnesium is less than 50mg kg-1 soil or 0,42 me per 100g topsoil. Ideally, the ratio of exchangeable Ca to Mg should be in the vicinity of 3.

This liming strategy is applicable only to soils that are not contaminated with sulphide minerals. Where the possibility exists of significant acid generation as a result of sulphide oxidation, required application rates for lime will be much greater and should be determined using acid-base accounting methodologies.

<u>Method of application</u>

Since the neutralising effect of lime is strictly localised, application in the usual way (broadcasting and ploughing or discing in) ameliorates only the surface layer to the depth of incorporation. The acidity of deeper material will remain unaffected. Subsoil acidity is a serious problem in many Highveld soils. Deep incorporation of lime is improved if it is spread prior to deep ripping, but deep ploughing is costly and not very efficient. The possibility exists of reducing subsoil acidity on rehabilitated sites by broadcasting lime in appropriate quantities on the soil prior to soil stripping. Relatively thorough incorporation should be ensured during handling and spreading operations resulting in amelioration throughout the entire depth of the new soil at very little additional cost. Lime may also be applied to spoils recognised as having an acid-forming potential prior to scarifying and topsoiling.

Nitrogen

Determining application rate

Soil tests for nitrogen are unavailable on a routine basis in this country. Amount and frequency of application is often a matter of experience although a reasonable figure for total seasonal requirement in the case of grasses may be arrived at as follows:

1. Decide on the production level desired (say Y kg of dry matter per hectare).

2. Calculate the internal N requirement (= X kg per ha) of the crop from: $X = \frac{C \text{ x } Y}{100}$

where C is the percent N in the herbage on a dry mass basis (in the absence of specific herbage analysis, a value for C of 1,5% N for a low production level rising to 2% for a high production level may be used.

4. Assume that the natural nitrogen supplying power of disturbed soil will be zero.

5. Assume a recovery factor (to compensate for leaching and volatilisation losses) of 70%.

6. For zero grazing (i.e. complete removal as hay or by fire) calculate the N requirement as the internal crop requirement adjusted by the recovery factor:

$$N\ requirement = \text{X x } \frac{100}{70}\ kg\ per\ ha$$

7. For grazed pasture, treat as zero grazed for two years after establishment and then reduce the amount calculated for zero grazing by 30%.

Method of application

Water-soluble forms of nitrogen (as present in most fertilisers) are highly mobile in the soil and are subject to loss by leaching and volatilisation. Consequently, the beneficial effects of a single dressing will last for a limited time only.

This, together with the fact that plant requirement varies with stage of growth and climatic conditions, accounts for the recommended practice of splitting the total nitrogen application into two or more dressings, provided that each of the latter exceeds a certain minimum quantity. It is generally regarded as uneconomic to apply a split dressing of less than 75 kg N per hectare unless it coincides with the application of other nutrients.

Nitrogen at establishment

The nitrogen requirement of pasture grasses during the first month after establishment is low. Under normal farming conditions, the natural supply from the soil is usually adequate and nitrogen is not applied at establishment. However, on freshly topsoiled land, vigorous early growth will be promoted by a small pre-plant application of 25 to 50 kg N per ha, irrespective of the species used. This may most conveniently be applied in conjunction with basal P and K through a suitable mixture which is broadcast and disced in during final seedbed preparation immediately prior to planting.

Annual maintenance dressings of nitrogen

Pasture plants other than legumes require a continuous supply of nitrogen from the soil during the period of active growth if vigour and palatability are to be maintained. A nitrogen budget should be worked out as described earlier and the pasture top-dressed with split applications starting one month after emergence and terminating about six weeks before the anticipated end of the growing season.

Grass-legume pastures that are grazed do not require regular nitrogen applications. They should, however, be kept under observation for signs of nitrogen deficiency. Zero grazed grass-legume pastures may have a small requirement of some 100 kg N/ha/annum.

To avoid acidification, limestone ammonium nitrate is the preferred N carrier.

Phosphorus

Phosphorus is invariably deficient, often acutely so in acid soils of high rainfall areas.

Determining basal application rate

A soil is capable of supplying adequate P to a high producing crop should analyse at about 36 ppm P using the Bray No.1 procedure. Lower levels, about 20 ppm P (Bray) should be adequate for restoration of lower productivity grasslands. Mine soils will invariably test lower than this and the deficit should be made good prior to the establishment of vegetation. Approximately 5 kg of P per hectare is required, on average, to raise the soil test value by 1 ppm. This rule of thumb may be used to calculate the basal dressing which should be in the water-soluble form.

Less soluble forms (e.g. sedimentary phosphate rock) are often recommended for basal (but not surface) application for pastures on acid soils in which case the total quantity of P applied should be doubled. To avoid damage to seed and emerging seedlings through direct contact with unreacted water-soluble P fertilisers, the latter should be applied prior to planting and must be thoroughly incorporated with the soil. All basal phosphorus applications should be thoroughly incorporated by ploughing into the plant rooting zone.

Annual maintenance dressing of phosphorus

Although the P content of herbage is low (0,2-0,3 %), an annual topdressing using a water-soluble P carrier is necessary even on grazed pastures because applied P tends to become decreasingly available to plants with time. The amount required should be assessed by soil analysis and will vary with the utilisation profile of the pasture. As a general guide, zero grazed pastures should receive at least 25, 35 and 40 kg of water- soluble P per hectare for low, medium and high levels of production, respectively. Legume-based pastures require 40 kg P irrespective of level of production.

Potassium

Grasses and legumes take up relatively large amounts of potassium and the level of exchangeable K in the soil should be in the vicinity of 120 ppm for high production levels. Analysis is particularly important in managing soil K status for the following reasons:

- Fairly wide fluctuations may occur as a result of leaching (particularly on sandy soils), fixation of applied K by clay minerals, and pasture utilisation pattern;
- An oversupply of K is wasteful because of luxury uptake by plants;
- Low topsoil K levels may be compensated for by subsoil reserves – a phenomenon that may be particularly relevant in the case of weathering spoil.

Potassium at establishment

The soil should receive a basal application designed to raise exchangeable K to a value of 120 ppm irrespective of subsoil reserves.

Annual maintenance dressings

In general, for zero grazing, soil levels should be kept at about 120 ppm exchangeable K by means of a single annual topdressing applied in the autumn to loams and clays and split into two in the case of sandy soils (< 15 % clay). In the absence of soil analysis, 150, 250, and 300 kg K per hectare may be applied for low, medium and high productivity, respectively.

Where spoil material is within rooting depth of the established pasture, its K status should be investigated as this, if high, may permit downward adjustment of the application rate determined using the above norms. Where pastures are grazed, recycling of K may be appreciable but will depend on the extent of occupancy. In this case K should be applied only on the basis of analysis.

Sulphur

In the industrialised areas of South Africa, and in areas close to the sea, general sulphur contamination of the environment through coal waste and dust, and aerosolic emissions of sulphur from coal burning power stations occurs. Sulphur deficiencies in these areas are highly unlikely to develop. Consequently, low- sulphur fertilisers (double superphosphate instead of single supers, and LAN instead of ammonium sulphate) can be used without risk of incurring a sulphur deficiency. In some other areas of South Africa, where industrialisation levels are lower, there may be a need to use fertilisers with higher sulphur content.

Calcium and magnesium

Calcium will not normally be limiting in well-fertilised pastures (due to additions through lime and phosphatic fertilisers) but magnesium may fall below the threshold of 50 ppm. This may be rectified by the use of dolomitic lime.

Minor elements

Molybdenum is the only minor element to limit growth on acid soils. Legume seed must be given a standard treatment of sodium molybdate equivalent to not more than 300g of molybdic acid applied to the quantity of seed used per hectare.

However, applications of lime to neutralise acidity may well induce other micronutrient deficiencies. Zinc deficiency is frequently observed and, less frequently, copper and boron deficiencies may develop.

Plants will normally grow out of minor zinc deficiencies, which manifest under overcast conditions and clear up when sunny conditions return. However, on some sandier soils and on those that have been over-limed, zinc deficiencies persist. These need to be ameliorated by the addition of zinc, either as zinc oxide, or as zinc-containing compound fertilisers. Likewise, boron deficiencies can be treated by the application of boron- containing compound fertilisers.

Appendix K: CONSIDERATIONS FOR VEGETATION SELECTION

Objectives of revegetation

Having reshaped a suitable topography and covered this with soil material, it is vital to establish, as rapidly as possible, permanent vegetation cover to protect the surface from water and wind erosion. The primary objective of revegetation is therefore to reduce soil movement to a minimum.

Revegetation also has other objectives. In the most mining operations the material used for topsoiling will be a blend of various soils horizons and possibly some saprolite. As a medium for plant growth such materials are invariably inferior to natural soil in that they are relatively low in organic matter, poorly aggregated, and probably contain a depleted microbial population. As a result, they tend to be less fertile, more droughty and more erodible than the natural soil, subject to compaction, and susceptible to the formation of surface crusts that inhibit seed germination and retard gas exchange between the soil and the atmosphere.

In order to ameliorate these unfavourable conditions, it is essential to re-establish carbon and nutrient cycles by keeping the land under a permanent vegetative cover for a number of years. Organic residues should as far as possible be retained in the cycle and not be removed. This paves the way for eventual crop or pasture production, or re-establishment of habitat as required by the biodiversity targets set for the area where appropriate.

Finally, there is the aesthetic consideration of restoring to the landscape a pleasing “natural” appearance and reducing the contrast between disturbed and undisturbed areas.

To summarise, the aims of revegetation are:

- to stabilise the soil and minimise erosion;
- to prevent pollution of streams and air by particulate matter;
- to re-establish nutrient cycles;
- to ameliorate soil physical properties;
- in the longer term, to re-establish naturally sustaining native plant ecosystems.

Criteria for selecting plants

Various practical considerations will determine the eventual success and sustainability of rehabilitation. Those relating to the choices of plant species for revegetation are among the most critical in determining sustainability. The application of the following criteria in each individual situation will assist in choosing a suitable type of plant cover, irrespective of whether the final objective is the generation of pastures for animal production, or the generation of a sustainable, biodiverse and natural habitat.

1. Only plants that are well-adapted to prevailing climatic conditions and post- establishment method of use should be used.
2. Plants of perennial habit must form the main basis of any revegetation programme. Annual species may have some role but only in providing rapid temporary cover in the initial stage of revegetation or as a component of mixtures containing perennials.
3. Among the species used, at least one must be fast-growing and capable of providing a good ground cover during the first growing season, given normal climatic conditions. Dryland establishment will usually be required.
4. The species chosen for any specific area of land must be tolerant of adverse soil conditions likely to be present there (for example, subsoil acidity and metal ion toxicities, salinity, droughtiness in sandy materials, high water table and surface soil crusting).
5. Good quality planting material and preferably seed (e.g. Government-certified) must be readily available with an assured source of supply.
6. Local agricultural experience regarding establishment, persistence, management and response to management is important, and no species should be considered for use unless or until such experience is available.
7. Preferred species are those known to have regenerative effect on soil through a prolific root system and large biomass, and a capacity to slow down water movement across the soil, i.e. they should preferably be sod forming.
8. In planning a revegetation programme, it is important to bear in mind the incremental nature of strip mining. The total area to be managed on a mine may become very large and species which require a sustained high level of management will present logistic and cost problems. Consequently, the plant species or succession of plant species employed should as far as possible be selected to fit into a system of management that requires low inputs. Generally, they should provide forage acceptable to animals so that they can be grazed.
9. Because the cost of inputs (fertiliser, labour, machinery) required to maintain a vegetative cover cannot reasonably be debited to rehabilitation for an indefinite period of time, they should at some stage become recoverable from an economic agricultural enterprise. Consequently, the plants chosen should not only have agricultural value (e.g. as forage or fodder) but they should also fit into a viable production system which may include a livestock component. Hence, they should produce forage of reasonable quality.

Choice of species

Considerable experience has been gained over the past 25 years regarding the suitability and sustainability of the various species used for planting rehabilitated land. The key objectives of rehabilitation have also changed. While 25 years ago, key objectives were the establishment of permanent pastures for intensive exploitation by grazing or the introduction of ley crops prior to the return to arable cropping, in recent times much greater emphasis has been placed on the re-establishment of biodiverse native grasslands. This is being done either by the introduction of the native species into existing pastures or, in some instances, by the re-establishment of the native species directly. This is easiest to achieve where soil containing the native seedbank is stripped and returned in a single action. The seed bank in stockpiled topsoil is usually severely depleted and requires reinforcement by the introduction of selected grasses, either by plug planting, thatching, or by planting of seed using gel planters.

The plant species that was most commonly used for rehabilitation 25 years ago, *Eragrostis curvula*, has fallen into disfavour because of the difficulty of managing it sustainably. While it establishes easily and provides good erosion protection, it proved problematic unless managed intensively by regular defoliation.

The following is a list of species in common use for rehabilitation in South Africa.

Tropical-subtropical grasses

The so-called tropical-subtropical grasses have traditionally offered the best means of revegetation in the surface coalfield areas of this country.

Digitaria eriantha (Smuts finger grass) and *Chloris gayana* (Rhodes grass) are currently the pasture grasses of choice for rehabilitation on the Highveld and KwaZulu-Natal, with the inclusion of *Eragrostis tef* as an annual nurse crop. Seed quality in the finger grass is often poor, while the seedling Rhodes grass is slow to develop and the grass sometimes does not persist under grazing. However, where it will grow well, Rhodes grass is an excellent choice. It is acceptable to livestock, it is nutritious, and has the added advantage of being stoloniferous.

The most common pasture grass mix used is that of Smuts finger, Rhodes and teff. The teff provides good cover in the first season; Rhodes tends to dominate in the second year, but thereafter, Smuts Finger becomes dominant, depending on the soil fertility levels.

In drier and warmer areas (e.g. the Springbok Flats), *Cenchrus ciliaris* may be the most suitable species. However, the seed is such that it is difficult to sow, and establishment is often poor. Because of this, Star grass, which unfortunately has to be established vegetatively, i.e. from runners, is more reliable. It is nutritious, acceptable to livestock, and strongly stoloniferous. Its lack of seed is really its only major disadvantage, and this may confine its use to steep slopes where establishment from seed is in any event generally unsatisfactory. In such sites, Star grass may be planted at intervals along the slope.

Provided conditions for growth are adequate, it will rapidly cover the inter-row areas.

Cynodon dactylon is frequently used in seed mixes. While it is rare for *Cynodon* to dominate the resultant sward, it frequently develops profusely in less favoured niches and provides a valuable erosion control function.

Temperate grasses

These are not well adapted to the summer rainfall areas except where the feasibility for irrigation exists. There are two situations where the use of temperate grasses may be indicated:

Steep and highly erodible sites and waterways may be established to grass during the autumn and thereby stabilised prior to the commencement of the rainy season;

Where the management system includes a livestock factor, it may be desirable to produce, from a limited irrigated area, a supply of green feed for the winter period, particularly in the cooler areas. In such cases, oats and Italian ryegrass are valuable annuals. Apart from these two situations, the use of temperate grasses is not indicated.

Legumes

Generally, temperate legumes will not do well on Highveld sites but some of the tropical legumes, in particular the trailing types, could be usefully incorporated in the planting mixture. Species like *Desmodium uncinatum, D. intortum* and *Glycine wightii* will provide an erosion-resisting cover and a supply of valuable forage. The nitrogen provided by these legumes will accelerate the build-up of biological activity within the soil. Such legumes are, however, suited only to relatively warm areas. They should be utilised leniently for they are intolerant of intense defoliation. They have not shown significant success over the past 25 years.

Although usually regarded as intolerant of acid soil conditions, lucerne has shown considerable success on rehabilitated land on the Highveld, but like the tropical legumes it requires specialised management if it is to survive. Although it should preferably be cut for hay, it will survive rotational grazing.

Where conditions are too droughty for lucerne, American Sweet clover or some of the vetches may do well. Sweet clover in particular, is an interesting possibility being extremely hardy, but it is less acceptable to livestock than lucerne. Unfortunately, it has an annual or biannual habit. It should not be used as a hay crop since mouldy sweet clover hay is poisonous to stock. Arlington lespedeza (*Lespedeza cuneata*) could possibly be used in acid, low-fertility situations in the Highveld.

The use of annuals

Annual grasses and legumes may be useful as a “nurse crop” with perennial species, but they should be sparsely planted so that they do not compete excessively. *Eragrostis tef* (summer) is extremely valuable for this purpose, but other annuals like Italian ryegrass (*Lolium multiflorum*) and oats (*Avena* spp) (autumn and winter), and buckwheat *(Fagopyrum sagittatum*), cowpeas (*Vigna spp*), babala (*Pennisetum typhoides*) and forage sorghums (summer) may also be used. The latter two species are, however, rather too tall growing for this purpose and, if they are used, very light seeding rates should be employed. It is worth stressing again that populations of these plants should not be so high that they offer severe competition to the perennials.

Trees and shrubs

Trees and shrubs are not particularly effective in soil stabilisation and should under no circumstances be used alone (i.e. without a grass under-story that has been previously established) because they will not protect the soil from water erosion. Trees and shrubs should, in particular, be excluded from use on steeply sloping impoundment walls and in containment areas for waste materials, because their rooting habit may result in early failure of the containment structure.

While trees and shrubs are not recommended for rehabilitation from the point of view of stabilising the surface, they do have a role to play in landscaping rehabilitated areas and in proving shade and shelter belts for stock; certain species may even be used to provide fodder. They should, however, be planted sparsely, particularly evergreen types which continue to use water in the winter and thus desiccate the soil excessively.

The choice of trees and shrubs that do well is extremely wide. However, a number of trees that were previously acceptable for rehabilitation use (e.g. Black locust, *Robinia pseudoacacia*) are now classified as category 2 or 3 invader plants, and care must be taken to consult the NBI Declared Weeds and Invader Plants lists before selecting plants for use on rehabilitation.

Appendix L: CONSIDERATIONS FOR DEMOLITION OF INFRASTRUCTURE

The methodology for demolition of infrastructure is based on the following key assumptions:

- The removal of infrastructure will occur at the time of general mine closure. Special measures to protect adjacent structures which may otherwise remain operational have not been considered.
- Infrastructure will be removed to a depth of 1m below ground level, or if more cost-effective foundations will be covered to a depth of 1m, provided this does not affect surface water runoff. Sub-surface structures will be backfilled or sealed off.
- All infrastructure will be demolished with the view that the only salvage will be scrap value.
- Should any structure or item have intrinsic value at closure greater than the scrap value, it could be recovered as long as the total rehabilitation cost is not increased. This option can only be evaluated at closure.
- Structures will not be dismantled but will be pushed over or dropped using explosives and then loaded for removal using mechanical equipment. This has a significant safety advantage in largely avoiding the necessity of workmen having to operate at heights.
- Underground workings will be sealed with shaft plugs.
- Underground infrastructure will be left in place unless the resale value warrants removal.
- Inert rubble will be removed to tailings dams or disposed of underground.
- Contaminated rubble will be assessed for degree of contamination and disposed of in the appropriate hazardous waste disposal sites.

Civil Work

Brick and concrete structures up to 8m in height

- Demolish structure by means of 28-ton excavator fitted with a hydraulic hammer.
- Cut reinforcing where relevant.
- Stockpile rubble ready for carting.
- Load by means of 28-ton excavator onto 10 m3 tipper trucks and remove rubble to the tailings dam or underground.
- Level and rip infrastructure footprint.
- Replace topsoil and rehabilitate.

Brick and Concrete structures up to 15m in height

- Demolish structure by means of 43-ton excavator fitted with a hydraulic hammer.
- Cut reinforcing where relevant.

- Stockpile rubble ready for carting.
- Load by means of 28-ton excavator onto 10 m3 tipper trucks and remove rubble to the tailings dam or underground.
- Level and rip infrastructure footprint.
- Replace topsoil and rehabilitate.

Headgears, stacks and high concrete structures

- Blast by means of explosives to reduce height of structure or else fell the structure by means of explosives.
- Thereafter, an excavator fitted with a hydraulic hammer will be used.
- Cut reinforcing where relevant.
- Stockpile rubble ready for carting.
- Load by means of 28-ton excavator onto 10 m3 tipper trucks and remove rubble to the tailings dam or underground.
- Level and rip infrastructure footprint.

Foundations, plinths, retaining walls, bases and slabs

- Demolish structures by means of 28-ton excavator fitted with a hydraulic hammer.
- Remove rubble to tailings dam or underground.
- Replace topsoil and revegetate.

Railways

- Remove railway lines, sleepers, railway electrification including sub-stations and signalling.
- Remove ballast to waste rock dump. It is assumed that the removal of ballast and associated rehabilitation of the surface will mitigate any historical spillages (including hydrocarbons) along railway lines and that no additional clean-up is necessary.
- In the event that this is not the case, additional removal of polluted materials is obligatory. Hydrocarbon spills can usually be biodegraded in situ
- Currently, there is no legal requirement to remove culverts, bridges or other concrete structures.
- Reshape embankments and other disturbed areas to minimise erosion risk.
- Rip affected areas and revegetation.

Roads

- Remove surface of tarred roads (200 mm).

- Rip surface (tarred and gravel roads).
- Regrade surface.
- Apply 300 mm of usable topsoil material and revegetation.

Steelwork

It is assumed that all steelwork will be scrapped, and the demolition process is based on this assumption. However, mild steel scrap and more expensive metals such as copper and aluminium fetch high prices and there are significant amounts of these metals in the average mine infrastructure

Structures up to 12m in height

- By means of 43-ton excavator fitted with a bucket, push the structure, slowly collapsing it.
- Make collapsed structure safe by spreading the steelwork for gas cutters to proceed. Hydraulic shears fitted to excavators will also be utilised.
- Any civil structure e.g. suspended floor slabs, columns, beams, ground floor slabs, plinths, bases and foundations will be removed by means of hydraulic hammer.

Structures greater than 12m in height

- In some cases, explosives will be used either to reduce heights or fell sections of the structure. In the case of stacks these will be felled by means of explosives.
- Mobile cranes will be used where applicable.
- Make collapsed structure safe by spreading the steelwork for gas cutters to proceed. Hydraulic shears fitted to excavators will also be utilised.
- Any civil structure e.g. suspended floor slabs, columns, beams, ground floor slabs, plinths, bases and foundations will be removed by means of hydraulic hammer.

Roof sheeting and cladding

- Where it is safe and economical to remove roof sheeting and cladding this will be carried out. Lifelines and safety harnesses will be used at all times.

Recovery of machinery and equipment

- Prior to demolition, existing craneage will be used as much as possible to remove machinery and equipment that has resale value.
- Where no existing craneage is available, then mobile cranes will be utilised.
- Machinery and equipment with no resale value will only be removed prior to demolition if this facilitates the process. Equipment containing oils must be drained and the used oils sent for recycling.