DEVELOPING MINE CLOSURE RISK RATINGS AND A POST-CLOSURE OPPORTUNITY FRAMEWORK FOR SOUTH AFRICA

M Cole, T Chimbganda, M Esau, A Abrams and J Broadhurst

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Developing Mine Closure Risk Ratings and a Post-closure Opportunity Framework for South Africa

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Background

Mining is deeply embedded in the history of modern South Africa and has played a major role in the country's geopolitical and socio-economic development. Although the contribution of mining to the country's GDP has declined since its peak in the 1980s, it continues to be a critical contributor to the national economy (7.5% of GDP in 2022) and the world's supply of extractive resources, most notably for platinum, chromium and manganese. Over 230 operating mines are located in a quarter of the country's local municipalities and are supported or hosted by over 360 diverse urban and rural communities, home to over 6.2 million people. Many of these communities and local economies are highly dependent on mining and thus vulnerable to the risks relating to mine closure. In recent years, several collaborative, multi-stakeholder projects have been initiated to explore post-mining land-use and economic succession planning in South Africa. Mine closure risks and opportunities are site specific, affecting different communities to varying degrees, at different times and in distinctive ways, depending on factors such as water resources, land capability, socio-economic profiles, economic diversity, public infrastructure and access to markets. Given these complexities, the national government, local government and other stakeholders need guidance in identifying high risk areas and suitable post-closure interventions to mitigate these risks on a case-by-case basis.

Aim and objectives

The overarching aim of this project was to produce national mine closure risk and opportunity maps and classifications to inform and support mine closure planning and policy in South Africa. The specific objectives were:

- To undertake a national assessment of mine closure risk for all operating mines in South Africa, and to map and classify them in terms of different mine closure risks;
- To investigate four diverse case studies for post-mining land use in gold, coal and platinum mining areas to inform a post-closure opportunity framework;
- To develop a framework for identifying post-mining economic opportunities based on environmental and socio-economic factors.

Methodology

A comprehensive literature review and assessment of public documents and academic articles on mine closure formed the foundation for the study. This was complemented by semi-structured interviews with relevant experts and stakeholders and attendance of webinars, conferences and seminars. This enabled a detailed review and assessment of the four identified post-mining land use case studies – the Impact Catalyst in Limpopo, the Green Engine initiative in Mpumalanga, and the Community of Practice Resilient Futures project and Bokamoso Ba Rona project in Gauteng – and the development of a post-mining opportunity framework that identified all post closure land use alternatives, influencing factors and selection criteria. In parallel, a draft risk rating system was developed with three components – likelihood of closure, social risk and environmental risk. For each component, influencing factors, indicators and weightings were defined and data were collected from national and global databases. The authors' previously developed mining datasets were updated and expanded. The risk rating system was tested with the case studies and weightings were adjusted accordingly.

The risk ratings and all the supporting datasets were plotted in ArcGIS. An online GIS tool – Mine Closure Risk and Opportunities Atlas for South Africa – was developed to communicate to a wide audience and to enable stakeholders to interrogate the results. The draft risk rating system and the Atlas were then tested with mine closure experts from academia, civil society, industry, multilateral agencies and government in a stakeholder workshop and follow-up semi-structured interviews. The risk ratings and the Atlas were both refined and updated based on the expert feedback, with additional data collected and analysed.

Results and Discussion

The study has produced three novel tools for mine closure planning, policy-making and management in South Africa. The mine closure risk rating system identifies mines and regions where mine closure is highly likely and needs immediate attention. It also ranks mines by environmental and social risk of closure, enabling the prioritisation of mitigation and intervention by mining companies and government. The post-closure land use framework provides a defined process for going about identifying the most suitable options based on participatory process that involves reviewing all possible alternatives, identifying influencing factors, and quantifying suitability indicators. Supporting the risk rating system and the land use opportunities framework is a comprehensive spatial database covering mines, processing plants, mining communities, land, water, energy, biodiversity, infrastructure and governance. Future research could see the expansion of the datasets incorporated into the three tools. Ideally the Atlas would be regularly updated as the underlying global and national datasets are updated.

The tools are aimed at supporting and informing a wide range of stakeholders, with particular effort given to ensuring mining community members are able to access information about their nearby mine. The functionality of the Atlas on all types of devices empowers the most vulnerable in society who often do not have a voice in post-closure discussions. It is hoped that this will support just economic transitions away from mining in different regions across the country. In addition, the Atlas could promote deeper discussions on mine closure management and planning amongst a diverse group of stakeholders, and support evidence-based decision-making. Finally, while the three tools have been developed for South Africa, the concepts, design and insights could be applied to any mining country in the world.

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ACRONYMS & ABBREVIATIONS

AfDB	African Development Bank
AGSA	Auditor-General of South Africa
AMD	Acid Mine Drainage
COP	Community of Practice
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DBSA	Development Bank of Southern Africa
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DPME	Department of Planning, Monitoring and Evaluation
DRDLR	Department of Rural Development and Land Reform
DSI	Department of Science and Innovation
DWA	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
ESG	Environmental, Social and Governance
FWRDWA	Far West Rand Dolomitic Water Association
GDP	Gross Domestic Product
GIFA	Gauteng Infrastructure Financing Agency
GIS	Geographical Information Systems
GSSA	Geological Society of South Africa
GVA	Gross Value Added
ha	hectare
ICMM	International Council for Mining and Metals
IDP	Integrated Development Plan
IRMA	Initiative for Responsible Mining Assurance
km	kilometre
LED	Local Economic Development
LM	Local municipality
MCSA	Minerals Council South Africa

Ml	megalitre
MPRDA	Mineral and Petroleum Resources Development Act
MRR	Mineral Resources and Reserves
Mt	million tonnes
MW	megawatt
NEMA	National Environmental Management Act
NEMWA	National Environmental Management Waste Act
NMCS	National Mine Closure Strategy
NWA	National Water Act
NWRS	National Water Resources Strategy
oz	ounces
PGM	Platinum Group Metals
SAAQIS	South African Air Quality Information System
SAIMM	Southern African Institute of Mining and Metallurgy
SAMREC	South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves
SLP	Social and Labour Plan
SMME	small, medium and micro enterprises
STATSSA	Statistics South Africa
SWSA	Strategic Water Source Area
TSF	Tailings Storage Facilities
WHO	World Health Organisation
WMA	Water Management Area
WRDA	West Rand Development Agency
WRDM	West Rand District Municipality

GLOSSARY OF TERMS

Closure	A whole life of mine process that typically culminates in the issue of a closure certificate in terms of Section 43 of the MPRDA, which includes decommissioning and rehabilitation.
Decommissioning	Part of the closure process that begins near or at the cessation of mineral production and incorporates removal of unwanted infrastructure, development of final landforms and the construction of specific closure components.
Direct mining jobs	Job at a mine or for a mining company whose activity falls under the ISIC sector classification. Includes mining occupations and non-mining management, administrative and support occupations within a mining company.
Financial provision	Section 1 of the MPRDA defines financial provision as meaning 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.
Indirect mining jobs	This category comprises: (i) jobs related to the mine supply chain, such as transporters of ore, or jobs that provide goods or service inputs for the extraction of ore or its downstream industrial uses, including in power plants; and (ii) jobs induced by mining activity, such as jobs that produce goods and services consumed by mine workers and their families (often referred to as “induced” jobs).
Life of Mine	An assessment of realistically assumed geological, mining, metallurgical, economic, marketing, legal, environmental, social, governmental, engineering, operational and all other modifying factors, which are considered in order to derive the years for which a mine can still operate economically.
Planned closure	Planned closures occur when the mining and processing ceases due to economic or operational requirements or when the ore reserve is exhausted.
Post-Closure	Post-closure defines the point at which decommissioning activities have ceased and post-closure management activities have commenced.
Reclamation	Reclamation focusses on returning land and/or infrastructure to a state where economic, environmental or human uses are possible
Regeneration	Re-establishment of ecosystem structure and function to an image of its prior near-natural state or replication to a desired reference ecosystem.
Rehabilitation	The return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the

	site and surrounding land. Reinstatement of degrees of ecosystem structure and function where restoration is not the aspiration.
Remediation	Often referring to abandoned mine sites, remediation aims to return sites to a physically and chemically stable state. This includes undertaking corrective actions to reduce environmental contamination to acceptable regulation-based standards
Repurposing	Repurposing utilises elements of the existing mining infrastructure (i.e. roads, mine housing, operational buildings) and the reconfigured aspects of the landscape (i.e. mine voids and mine features) for a different activity post closure. This activity purposefully assists in transitioning the local economy and mitigates the loss of the mine by building on and/or establishing new forms of attachment to the site and region.
Reserve	The economically mineable material derived from a Measured and/or Indicated Resource
Resource	A concentration or occurrence of material of economic interest in or on the earth's crust in such form, quality and quantity that there are reasonable and realistic prospects for eventual economic extraction.
Temporary Closure	The phase following temporary cessation of operations when infrastructure remains intact, and the site continues to be managed. Care and maintenance are often required for operations that have temporarily ceased operations.
Unplanned closure	Unplanned closures occur when mining and processing suddenly cease due to financial constraints, if the operations are instructed to close due to non-conformance with regulatory requirements, or force majeure.

CHAPTER 1: BACKGROUND

1.1 Introduction

Mining is deeply embedded in the history of modern South Africa and has played a major role in the country's geopolitical and socio-economic development. Although the contribution of mining to the country's GDP has declined since its peak in 1980, it continues to be a critical contributor to the national economy (7.5% of GDP in 2022) and the world's supply of extractive resources. Whilst dominated by platinum, coal, gold, diamonds and ferrous metals, 20 major commodities are currently produced in 232 mines, operated by 92 mining companies. These operations are supported or hosted by 350 communities (cities, towns, townships, mine villages and rural villages) across South Africa, home to over 6 million people with diverse living conditions strongly influenced by their location and history. Most of these communities and local economies are highly dependent on mining and thus vulnerable to the negative impacts of mine closure.

South Africa's Mineral and Petroleum Resources Development Act (MPRDA) of 2002 and the more recent Draft National Mine Closure Strategy 2021 recognise the need to integrate mine closure across the whole life cycle of a mine, on a regional scale, and to make adequate financial provisional for this closure. In recent years, several collaborative, multi-stakeholder projects have been initiated to explore post-mining land-use and economic succession planning across the country. These include the Impact Catalyst in Limpopo, the Green Engine initiative in Mpumalanga, and the Community of Practice Resilient Futures project and Bokamoso Ba Rona project in Gauteng. Mine closure risks and opportunities are site specific, affecting different communities to varying degrees, at different times and in distinctive ways, depending on factors such as their size and remoteness, the local infrastructure and business activity, and the pre-closure socio-economic well-being. Given these complexities, the national government, local government and other stakeholders need guidance in identifying high risk areas and suitable post-closure interventions to mitigate these risks on a case-by-case basis.

1.2 Project aim and objectives

The overarching aim of this project is to produce national mine closure risk and opportunity maps and classifications to inform and support mine closure planning and national policy. The specific objectives include:

- To undertake a national assessment of all communities hosting large-scale mines in South Africa, and to map and classify them in terms of risk of mine closure and impact.
- To investigate four diverse case studies for post-mining land use in gold, coal and platinum mining areas.
- To develop a framework for identifying post-mining land use opportunities based on natural and socio-economic factors.

1.3 Scope and limitations

The project was conducted in three phases described below.

Phase 1: Development of frameworks for mine closure risks and opportunities

In the first phase of the project, initial frameworks for the ranking and scoring of mine closure risks and opportunities were based on a review and assessment of public documents and academic articles; semi-structured interviews with relevant experts and stakeholders; and attendance of on-line webinars, conferences and seminars. Three separate but inter-related frameworks were developed in three consecutive tasks:

- Task 1.1 entailed the development of a mine closure risk rating system based on literature and a workshop with mine closure experts;
- Task 1.2 entailed a detailed review and assessment of the four identified post-mining land use case studies in Limpopo, Gauteng and Mpumalanga based on document analysis, semi-structured interviews with relevant stakeholders, and attendance of project initiative workshops;
- Task 1.3 entailed the development of a post-mining land use opportunity framework that identified all post closure land use alternatives, influencing factors and selection criteria.

Phase 2: Data collection and Atlas development

In Phase 2 of the project, the framework developed in Phase 1 was used to rank and score mine closure risks based on publicly available datasets and research. A Mine Closure Risk and Opportunities Atlas for South Africa was developed in ArcGIS to visualise all the data collected and make it easily accessible and useable.

- Task 2.1 involved the collection of data and calculation of likelihood of closure, social and environmental mine closure risks for every mine, and these were plotted on maps and in the Atlas. This identified where mines are likely to close first, and which communities and natural environments are at high risk from mine closure across South Africa.
- Task 2.2 involved the identification and collection of quantitative data for the assessment of post-mining land use opportunities based on parameters identified in Task 1.3. These datasets were incorporated into the Atlas.

Phase 3: Refinement of rating system and frameworks

In Phase 3 of the project, the mine closure risk rating and opportunity framework developed in Phase 1 and 2 was reviewed and refined by testing the rating systems (i) against the knowledge gained from the four case studies (Task 1.2) and (ii) with mine closure experts and other stakeholders in a multi-stakeholder workshop and semi-structured interviews. Additional data were collected and the Atlas was updated.

CHAPTER 2: LITERATURE REVIEW

2.1 Mine closure context in South Africa

2.1.1 Overview of mining in South Africa

Mining has played a central role in the development of modern South Africa and shaped political, social, and economic paradigms for more than 150 years. World class mineral discoveries, diamonds in 1870 and gold in 1886 led to massive immigration and urbanisation (Bundy and Cobbing, 2019), with further globally significant discoveries of coal, manganese, iron ore and platinum group metals (PGMs) providing the basis for economic growth and development in the country over the next century. Many of the country's towns and cities having been developed alongside mines since the start of modern mining of copper in 1852 (Fig 2.1) (Cole and Broadhurst, 2020). There are over 350 mining host communities, categorised as cities, towns, townships, mine villages and rural villages, currently hosting or directly supporting mining of South Africa's 17 major commodities – coal, gold, diamonds, PGMs, chrome, nickel, copper, iron ore, manganese, vanadium, heavy minerals (ilmenite, rutile, zirconium), lead, zinc, silver and fluorspar (Fig. 2.2). These mining host communities are close to 230 operating mines run by 80 mining companies, comprise a total population of over 6 million (12% of South Africa's total in 2011) and cover an area of 9,193 km^2 (0.75% of South Africa). The biggest populations are found in coal (42%), gold (27%), platinum (16%) and diamond (8%) mining areas (Cole and Broadhurst, 2021).

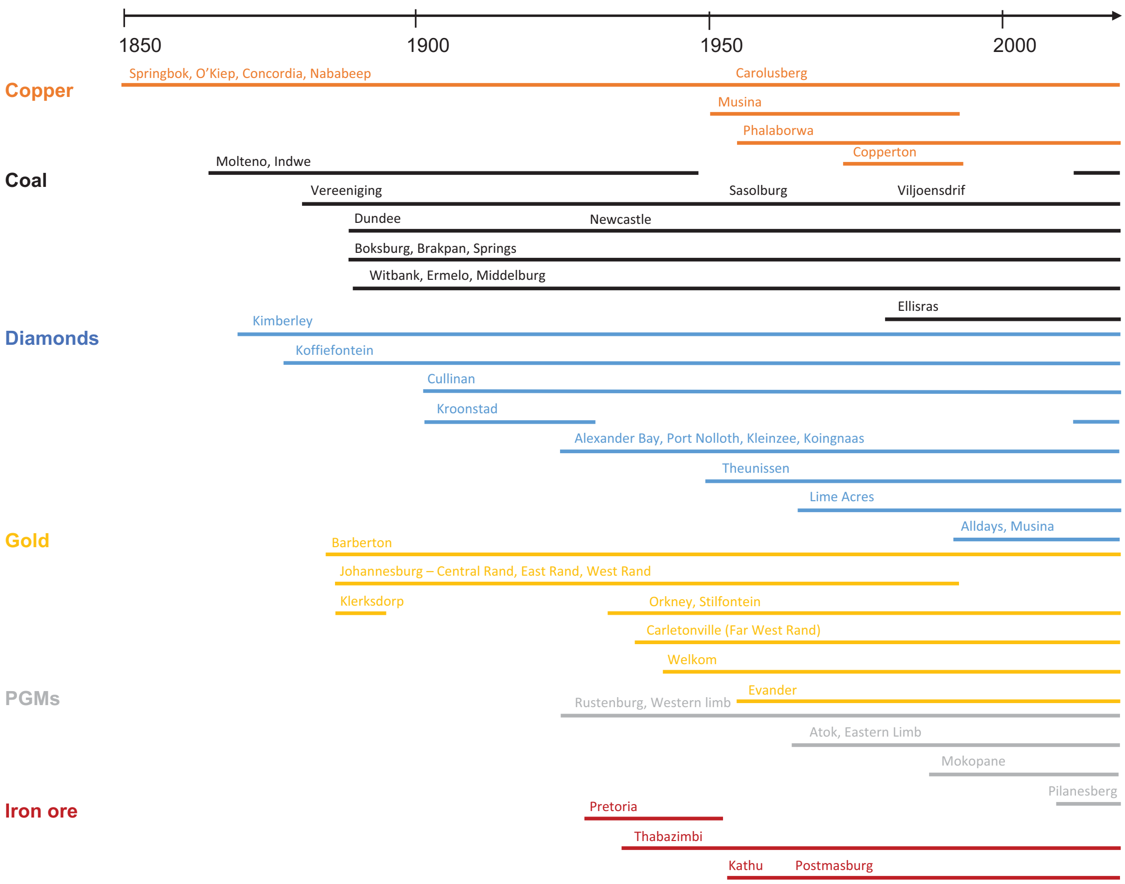


Figure 2.1 Timeline of community development associated with large-scale mining of major commodities (Cole and Broadhurst, 2020).

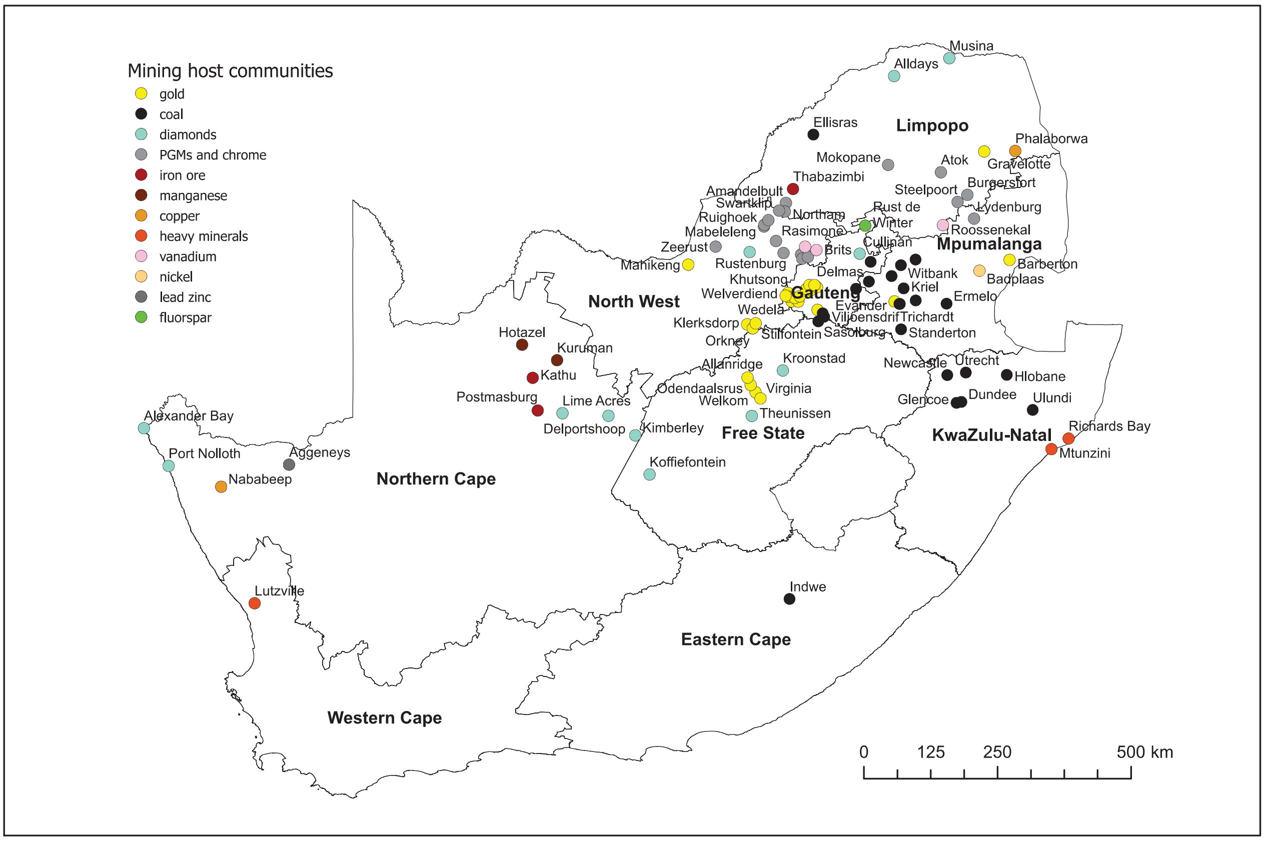


Figure 2.2 Location of mining host towns and cities within South Africa (Cole and Broadhurst, 2021)

The sector remains a critical economic activity and supplier of many primary and processed mineral and metal commodities, as indicated in Table 2.1. South Africa holds the world's largest reserves of PGMs (91%), chrome ore (75%), fluorspar (75%) and manganese ore (36%); and has significant reserves of zirconium (19%) and titanium (18%), and, to a lesser extent, gold (11%) and nickel (5%) (USGS, 2023a-g). The country is a leading producer of platinum (74%), palladium (38%), manganese ore (29%), chrome ore (36%), vermiculite (34%), zirconium (23%) fluorspar (5%), coal (3.2%) and gold (3.5%), as well as diamonds, coal and iron ore (USGS, 2023a-g; BP, 2022; SADPMR, 2022). The South African mining industry is primarily export driven, with export sales valued at R323.8 billion in 2022 compared to local sales at R203.7 billion in 2022. The biggest contributor to export sales in 2022 were PGMs (28.9%), followed by coal (17.6%), iron ore (17.5%) and gold (14.9%). Local sales are dominated by coal which contributed 44.6% of local sales in 2022, followed by PGMs (19.3%), chromium ore (6.4%) and gold (6.2%).

Mining was at its peak in 1980 contributing 21% of national gross domestic product (GDP) and has since declined to 8.2% of GDP in 2020, with a value of R361.6 billion (MCSA, 2020). This can be largely attributed to the dramatic decrease in the production of gold, and the related primary products of silver and uranium, as well as declining production, exploration expenditure and employment in the last decade, due to rising operating costs and declining capital investment amidst an uncertain regulatory framework (DMRE, 2018a). In 2022, the mining industry employed 475,561 people, the majority of whom work in PGMs (36%), gold (20%) and coal (19%) (MCSA, 2023). In 2007, it was estimated that each mining employees supported between 7 and 10 dependants (Chamber of Mines of South Africa, 2007), bringing the number of people depending on mining for a living to between 3 and 4.5 million. Mining sector employment gains since 2009 have occurred in coal, manganese, iron ore and chrome sub-sectors, while significant employment losses have occurred in the gold, PGM and diamonds sub-sectors, shown in Figure 2.5 (MCSA, 2020). Most mining employees are employed directly by the mining company, although almost a third are employed as sub-contractors and about 5% are employed through labour brokers. Women currently make up only 14% of the total employees (MCSA, 2020).

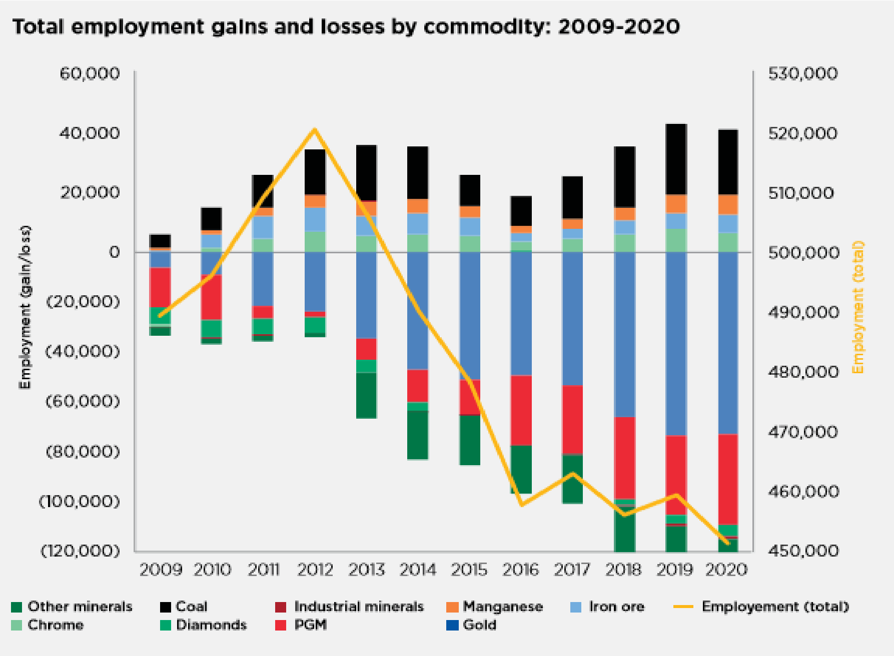


Figure 2.3 Total mining employment gains and losses by commodity from 2009-2020 (Minerals Council South Africa, 2020)

The mining sector is one of the main consumers of energy, particularly through its electricity demands, which accounts for approximately 70% of its total energy consumption (DMRE, 2019a). The remaining energy sources are petroleum products (26%) and coal (4%), with some natural gas. Mining and quarrying accounts for 10% of the country's energy consumption while the downstream iron and steel sector consumes 18% of and non-ferrous and non-metallic minerals consumes 8% and 5% respectively.

The focus of mine closure in South Africa has shifted from the gold mines in the Witwatersrand basin to the coal mines in Mpumalanga as reserves and resources are depleted and the world shifts to renewable energy sources (Cole et al., 2023). This could have very negative effects on communities and local municipalities, particularly those with poor governance (Cole et al., 2023; Marais et al., 2021). In other regions within South Africa, the increased global demand for so called "energy transition minerals", such as PGMs, iron ore, manganese, base metals and vanadium, which are all crucial to emerging green energy and e-mobility technologies, may precipitate a resurgence of mining activity (MISTRA, 2018). Whilst this creates an opportunity for economic development both locally and nationally, it will be critical to ensure that new or revived mining activities do not leave behind negative social and environmental legacies. This includes consideration of the socio-economic consequences of future mine closures, which have historically received less attention than environmental impacts (Marais and Nel, 2016), but are now recognised as being the most critical risk facing the sector (EY, 2021).

2.1.2 Governance and legacies of mining in South Africa

Historically, the benefits of mineral wealth have not been shared equitably and the mining industry has been largely built on the back of exploitation and inequality, entrenched through colonialism and, later, apartheid.

The lack of adequate legislation and poor practices on the part of the industry in the past have left a legacy of abandoned mines, degraded lands and polluted environments, with concomitant effects on the health, quality of life and livelihoods of local communities (Krause and Snyman, 2014). South African mining in 2023 is operating under very different socio-political and regulatory conditions than in the previous two centuries, with several broad-based regulatory changes since the birth of democracy in 1994 having been a powerful force for change in the industry. In particular, the Minerals and Petroleum Resources Development Act of 2002 (MPRDA) has been specifically developed to redress historical inequalities and ensure that the mining industry contributes to socio-economic development.

The MPRDA is effected through the 'Broad-Based Black Socio-Economic Empowerment Charter for the Mining and Minerals Industry, commonly known as the Mining Charter (DMRE, 2018a), the Guideline for Implementation of a Social and Labour Plan (DMRE, 2010) and the Housing and Living Conditions Standard (DMRE, 2019b). The MPRDA eliminated private ownership of mineral rights and vested it in the people of South Africa under custodianship of the state, whilst the Mining Charter requires new mining rights to have 30% Black Economic Empowerment shareholding which includes a 5% equity equivalent benefit for host communities. The Social and Labour Plan (SLP) sets out how the company intends sharing the benefits of mining with the mine communities (CALS, 2016), which include host communities as well as labour sending areas, defined as areas from which a majority of mineworkers, both historical and current are or have been sourced (DMRE, 2010). Amendments to the National Environmental Management Act (NEMA) and the Mine and Safety Act, along with programmes such as the 'Revitalisation of distressed mining communities and labour sending areas' programme launched by the Department of Planning, Monitoring and Evaluation (DPME) in 2012, have further contributed to efforts to make the mining sector more equitable and address negative environmental legacies.

The management of public health and safety impacts and environmental impacts on both surface and ground water and air quality of abandoned mines has become a significant burden to the government (Marais and Nel, 2016; Watson and Olalde, 2019). A performance audit in 2009 by the Auditor-General of South Africa (AGSA) of rehabilitation of abandoned mines showed that the DMRE did not have measures in place to record and report on the status of abandoned mines and had focused its efforts on abandoned asbestos mines due to the associated health risks (AGSA, 2009). The DMRE compiled a national database of 5,906 officially listed abandoned 'mines' (including quarries, adits and mine dumps) and the Council for Geoscience ranked these sites in terms of their potential impact on public health, safety and the environment and identified 1,730 high risk mines were asbestos, gold, copper and coal mines with an estimated cost of rehabilitation of R30 billion (DME, 2009), while over half of these sites do not need rehabilitation (PMG, 2017).

Despite the promulgation of progressive regulatory reforms and government initiatives, the human and environmental impacts of historic mining operations continue to be an issue with many mining-affected communities impacted by the negligence of historic mining activities. A recent study of the socio-economic well-being of mining host communities in South Africa by Cole and Broadhurst (2021) has shown that hundreds of thousands of people in these communities are deprived of basic services, secondary education and decent jobs. Of particular concern was the finding that small towns in close proximity to large-scale mines tend to have the lowest well-being scores. The study highlighted the significant variances in the levels of well-being amongst the 95 communities investigated. This variance was attributed to the legacy of South Africa's apartheid policies of racial segregation and systemic inequality and reflect the national situation, with more than 55% of the population living below the poverty line and unemployment at unprecedented levels (Cole and Broadhurst, 2021). Apart from access to jobs and services, many of these communities are also impacted by environmental pollution from both active and defunct mines and waste dumps. This is particularly problematic in communities surrounded by a significant number of derelict and ownerless mines, historically occurring in the copper districts in the Northern Cape, the goldfields in Gauteng and the Free State and the coalfields in Kwazulu-Natal, but also in asbestos mining areas and the Pretoria silver belts (Cole and Broadhurst, 2021; Hart, 1998 and Reeks, 2012). Whilst these impacts have not been limited to disadvantaged communities alone, a recent study (IHRC, 2016) indicated that poor and disempowered communities often bear the brunt of the pollution impacts. Residents of these areas are often not aware of the dire health risks they are exposed to (Manungufala et al., 2005), and if they are, they are often reluctant to raise the issue (Bobbins, 2015).

The general perception amongst stakeholders is that government and industry are failing in their efforts to effectively address the negative environmental legacies of mining in South Africa (IHRC, 2016; SAHRC, 2016), and to provide the anticipated socio-economic benefits to mining host communities (Bruechner et al., 2021; Marais et al., 2021). This is consistent with the Responsible Mining Index (2020) claim that there is a general disconnect between company policies and standards versus on-the-ground actions at mining sites across the globe. Similarly, Gule (2021) found that current rehabilitation practices in opencast coal mines in South Africa are not to the quality prescribed by sectoral or even in-house company standards. Furthermore, despite advances in government regulations and policies, these are often considered to remain deficient, inconsistent and onerous in their application (Shongwe, 2018; Stander and Broadhurst, 2021). There is a perception that there is inadequate enforcement of environmental and closure regulations in South Africa. A study by Shongwe (2018) indicated that this can be attributed, at least partly, to political interference and the unethical relationships between government officials and certain mining corporations and/or traditional leaders.

Regions of mine closure in South Africa are the Okiep copperbelt (1852-1970s), the Natal coalfields (1880s-1980s), the asbestos mines in the Northern Cape (1930s-1980s), Wits goldfields (1886-1990s), Rooiberg tin (1907-1994) and West Coast diamonds (1926-2010), as shown in Figure 2.4.

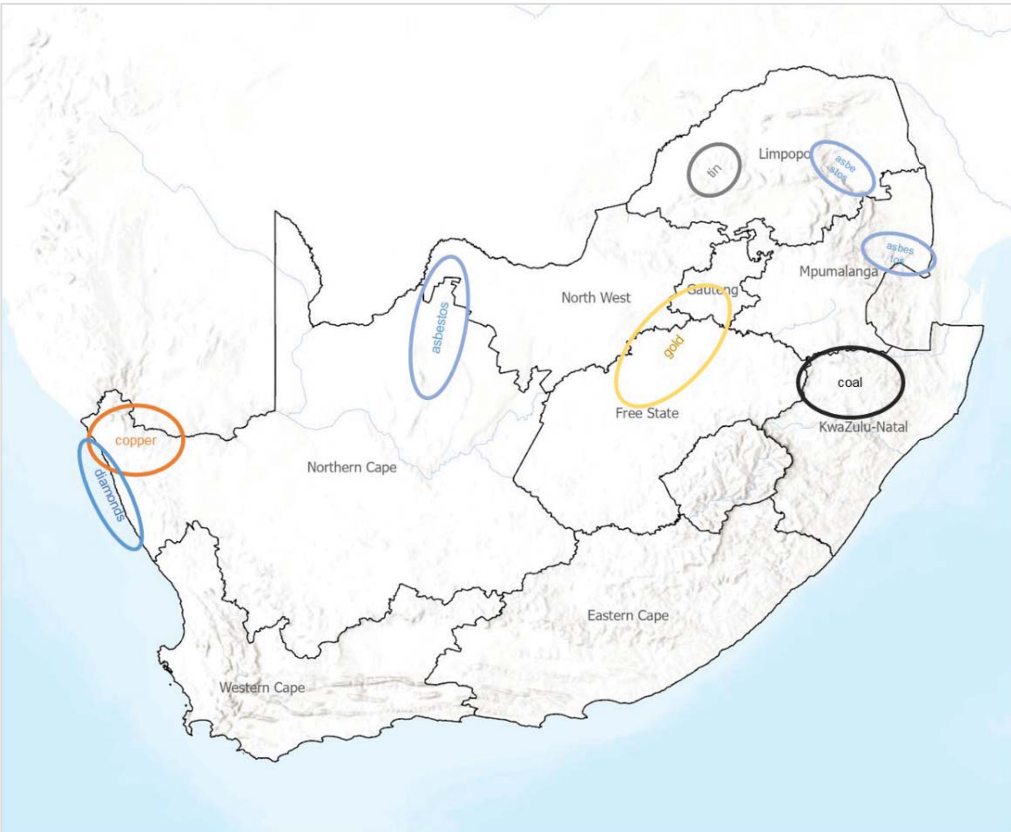


Figure 2.4 Regions of historical mine closure in South Africa

2.2 Mine closure planning

2.2.1 Overview of mine closure planning

Considerable concern exists around the potential impacts of on-going and future mine closures over the next few decades (Brock, 2021). Mine closure is commonly associated with the rehabilitation of a depleted mine site and the decommissioning of associated facilitates and other infrastructure (Laurence, 2006; Nehring and Cheng, 2016; ICMM, 2019). The negative environmental, social and economic impacts associated with mining activities are often magnified or become more apparent in the mine closure and post-closure phases. Acceptable planning practice requires that mine closure planning starts at the onset of mining activity, with a conceptual plan during the exploration phase, increasing in detail over the various stages of the life of mine (ICMM, 2008; 2019). In reality, mine closure planning is a complex process which needs to integrate across various social, environmental, and economic considerations, while incorporating multi-stakeholder needs and operating within regulatory frameworks over the life of mine, as shown Fig 2.5 (Government of Western Australia, 2020; ICMM, 2019).

In practice, adequate closure plans are often not developed in the early phases of planning with only broad objectives being set (Laurence, 2006; Nehring and Cheng, 2016; Fawcett and Laurencont, 2019). The development of detailed mine closure plans tends to be deferred until a later stage, resulting in unmanaged impacts and liabilities which often leads to many operations being eventually placed on “care and maintenance” (Laurence, 2006; Kabir et al., 2015; Nehring and Cheng, 2016; Fawcett and Laurencont, 2019). Guidelines and frameworks (discussed further in Section 2.2.2) have therefore been developed by several government bodies and various institutions to inform best practices and guide the closure planning process.

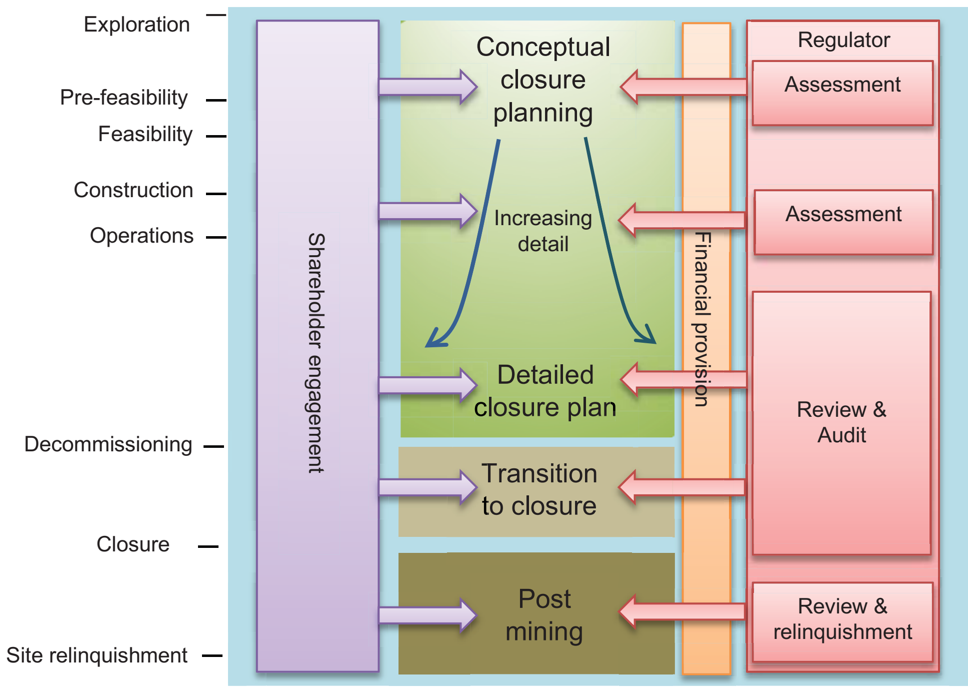


Figure 2.5 Closure planning over the various stages of the life of mine (ICMM, 2019; Government of Western Australia, 2020)

2.2.2 Mine closure guidelines, frameworks and best practices

There are several principles and guidelines that have been developed to guide the mining industry towards a positive contribution to sustainable development over the life of mine (MMSD, 2002; ICMM, 2003; IRMA, 2014). Due to the increasing awareness of the role mine closure plays in responsible mining practices, various frameworks and guidelines have been further developed over the last 20 years to specifically address mine closure (ANZMEC, 2000; IRMA, 2018; ICMM, 2019; Government of Western Australia, 2020). With planned closures expected to increase over the next decades a number of these guidelines have been under review over the last five years as the mining industry redefines approaches to closure and post-mining development (IRMA, 2018; ICMM, 2019; Government of Western Australia, 2020; World Bank 2021). Many of these guidelines detail key elements of mine closure planning and best practices, such as setting objectives, environmental management, monitoring and management that should increase in detail and accuracy through the mine life cycle stages as shown in Figure 2.6.

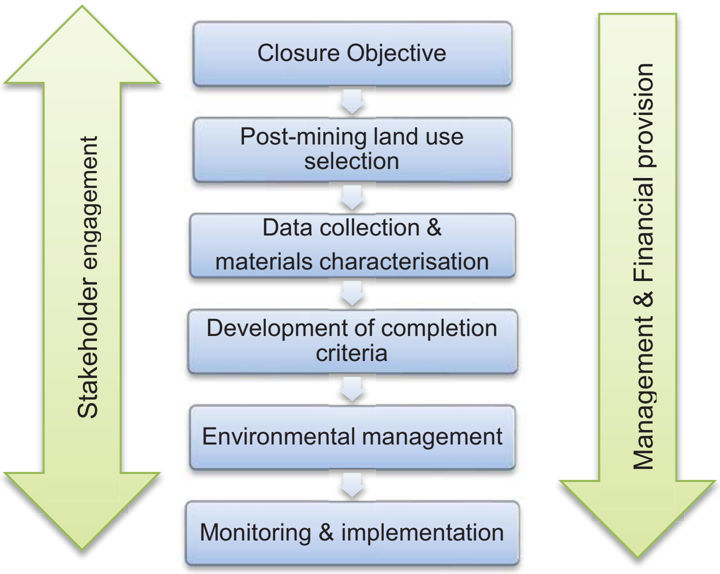


Figure 2.6 General framework and best practice guideline for mine closure planning

The ICMM's initial guideline which was published in 2008 promoted an integrated approach to mine closure that incorporates mine closure planning over the life of the mine, with the revised version in 2019 highlighting the need for the process to be progressive, dynamic and iterative taking into account environmental, social and economic issues. IRMA on the other hand places an emphasis on legacy development and includes closure guidelines as part of planning for positive legacies in its standard for responsible mining which was first drafted in 2014 and revised in 2018, with further revisions underway in 2021. The Anglo American mine closure toolbox, which was initially released in 2013 to optimise designing, planning and execution of closure activities at operations, was updated in 2019 to put more emphasis on stakeholder engagement in mine closure processes. The World Bank which recently published a mine closure governance framework in April 2021 specifically targets policy, legislation and practices that should be implemented as part of closure planning over the mine life cycle. More mature mining jurisdictions such as Canada and Australia have mine closure guidance documents that highlight consideration for regional contexts (Kabir et al., 2015; Canada Ministry Energy and Natural Resources, 2017; Government of Western Australia, 2020). Most of the best practice guidelines and frameworks broadly detail for closure to be successful the following objectives need to be satisfied:

- Establishment of post-mining land and infrastructure use,
- Protect public health and safety,

- Alleviate or eliminate environmental impacts and, thereby, encourage environmental sustainability,
- Conserve valuable pre-mining site attributes, and
- Minimize adverse socio-economic impacts.

More recently published guidelines promote progressive rehabilitation and the necessity mine closure activities to be integrated in core mining operations (IRMA, 2018; Anglo American, 2019; ICMM, 2019; World Bank 2021). Despite the existence of these guidelines, the mine closure process remains complex, and establishing sustainable post-mining land-uses and social transitions continue to be a global challenge (Kabir et al., 2015; McCullough, 2016; Bainton and Holcombe, 2018; Fawcett and Laurencont, 2019). Due to these challenges the various best practices guidelines address these aspects to varying degrees as shown in Table 2.1.

Table 2.1 Review of global Mine Closure Guidelines and best practices

Evaluation criteria		ICMM Toolkit[1]	Anglo American Toolbox[2]	Canada Quebec Guidelines[3]	Western Australia Guidelines[4]	IRMA Standard[5]	World Bank Toolkit[6]
Stakeholder engagement	Multi-stakeholder engagement promoted across activities?	□	□	□	□	□	□
	Provides framework for stakeholder engagement	W	W	¡	¡	¡	¡
Closure objectives	Requires specific and clear mine closure objectives	¡	¡	¡	□	¡	¡
	Post-mining land use considerations clearly detailed?	¡	¡	¡	¡	¡	W
Data collection & materials characterisation	Defines materials and data measurements	¡	¡	□	□	□	W
Completion criteria	Details performance criteria and indicators	W	W	¡	¡	¡	W
Environmental management	Management criteria clearly stated?	¡	¡	□	□	□	¡
	Integrates progressive rehabilitation	¡	¡	□	□	□	¡
Monitoring and implementation	Defines environmental monitoring criteria	¡	¡	¡	□	□	¡
	Details socio-economic monitoring criteria	W	W	W	W	W	¡
	Details management of social risks	¡	¡	¡	¡	¡	W
Financial provision	Clear details on estimation	¡	□	□	¡	□	¡

	Promotes frequent review of estimations	W	¡	¡	¡	□	□

Key: □ Fully-defined ¡ Semi-defined W Unclear

1. International Council on Mining and Metals (ICMM) 2019. *Planning for Integrated Mine Closure: Toolkit.*
2. Anglo American 2019. *Mine closure toolbox version 3.* Johannesburg: Anglo American plc.
3. Ministry Energy and Natural Resources, Canada, 2017. Guidelines for Closure Planning in Quebec.
4. Government of Western Australia 2020. *Guidelines for Preparing Mine Closure Plans.* (Revision of the Guidelines for Preparing Mine Closure Plans, June 2015). Australia: Department of Mines and Petroleum, Environmental Protection Authority.
5. Initiative for Responsible Mining Assurance (IRMA) 2018. *IRMA Standard for Responsible Mining.* (IRMA-Standard v1.0).
6. World Bank 2021. Mine Closure: A Toolbox for Governments. *World Bank Energy and extractives.*

Setting objectives for mine closure from the onset of mining is largely stipulated across most guidelines, with the most important aspect of these objectives being the intended post-mining land use as this should form the basis of much of the closure completion criteria (Fawcett and Laurencont, 2019). However, considerations around mine closure objectives and post-mining land use continue to focus on environmental management and rehabilitation, with the management of social risks not fully addressed (Bainton and Holcombe, 2018; Ackerman et al., 2018). Most of the guidelines detail the need for stakeholder engagement across all the key elements of closure planning. However, the details around the approach to stakeholder engagement and their extent is not always clear.

Across the guidelines there is general consensus on how effective data collection ensures that risks are managed and monitored and is important in establishing adequate measurements for closure completion criteria (Coppin, 2013; Kabir et al., 2015; Manero et al., 2020). The emphasis of performance indicators continues to be on environmental indicators, with socio-economic impacts and social risks often understated (Bainton and Holcombe, 2018; Beckett et al., 2020; Manero et al., 2020). There is also not much consensus in many of the guidelines on which criteria and indicators are the best to use, making it difficult to assess “successful closure” (Coppin, 2013; Manero et al., 2020). The need for continuous management of risks and adequate financial provision to address active planning and costs requirements is emphasised in most guidelines. However, the approach to financial provision estimations differs and as well as how to incorporate the costs of progressive rehabilitation (Nehring and Cheng, 2016).

Mine closure guidelines and best practices have vastly progressed over the last 10 years, however much of the focus is still placed on environmental aspects, with much progress still to be made on addressing social aspects of closure and managing social risks (Limpitlaw and Mitchell, 2013; Bainton and Holcombe, 2018; Manero et al., 2020).

2.2.3 Mine closure practices and policy in South Africa

South Africa’s legislative frameworks and policy around mine closure generally conform to international guidelines (Alberts et al., 2017; Watson and Olalde, 2019), However, successful mine closure in South Africa remains a challenge (Perkins et al., 2020). The mine closure policy space in South Africa is complex, involving various legislation and different government departments (Watson and Olalde, 2019).

Mine closure policy and legislation

The early mining laws in South Africa (e.g. Transvaal Mining Laws 1903) only required fencing of sites and the making safe of dangerous openings and environmental rehabilitation was only required from 1956 with the Mines and Works Act 27, although some remediation with regards to contaminated water was required in the earlier Water Act (DMR, 2009). Closure planning became a requirement in the Minerals Act of 1991, which stipulated that an Environmental Management Programme (EMP) be submitted, rehabilitation be undertaken, financial provision made, and an application submitted for a closure certificate (Swart, 2003). Since then, there have been significant legislative reforms to mining and environmental legislation (Alberts et al., 2017). The main regulations which govern mine closure and rehabilitation in South Africa are the Mineral and Petroleum Resources Development Act (MPRDA) 2002 and the National Environmental Management Waste Act (NEMWA).

The MPRDA 2002 with later revisions broadly specifies rehabilitation obligations and financial provisions for mine closure (Swart, 2003). Under Section 38 (1) (d) of MPRDA (2002): *The holder of a reconnaissance permission, prospecting right, mining right, mining permit or retention permit must as far as reasonably practicable rehabilitate the land affected by the operation to its natural or predetermined state, or to a land use which conforms to the generally accepted principle of sustainable development*. Environmental provisions are contained in the National Environmental Management Act (NEMA) and water use for mining related activity is governed by National Water Act (NWA). The implementation of NEMA is facilitated by various supporting environmental management acts; the National Environmental Management Waste Act (NEM: WA), National Environmental Management Biodiversity Act (NEM: BA) and National Environmental Management Air Quality Act (NEM: AQA). Mine closure planning and rehabilitation activity were largely governed by the MPRDA, however in 2015, regulations for Financial Provisioning for the Mitigation and Rehabilitation of Environmental Damage Caused by Reconnaissance, Prospecting, Exploration, Mining or Production Operations were promulgated under GNR1147 in terms NEMA. Under the GNR1147 every mining operation is required to submit a rehabilitation plan, environmental risk report, and final rehabilitation and mine closure plan. The One Environmental System was subsequently implemented to align the MPRDA, NEMA and supporting environmental management acts and the NWA (Fischer at al., 2015; Marais, 2013; Krause & Snyman, 2014; Alberts et al., 2017).

There are several other regulations which are relevant to mine closure and post-mining land use planning. The Mine Health and Safety Act places safety and occupational obligations on mine rehabilitation and closed mines. Supporting legislation contained in the Conservation of Agriculture Act and Spatial Planning and Land Use Management Act, which govern natural resources use and land-use management respectively, is important for post-closure and post-mining land use planning. Mining companies are also required to provide SLPs as a prerequisite to securing mining rights, SLPs are intended to address socio-economic issues associated with mining and integrate with the municipalities' Integrated Development Plans (IDPs) and local economic development (LEDs) plans (Marais, 2013). However, SLPs, IDPs and LEDs focus more on living conditions, with limited integration with mine closure activities and post-mining land use considerations (Tshangana, 2015; Marais et al., 2017; Campbell, Nel & Mphambukeli, 2017). Regional land use planning is contained within IDPs and LEDs, however the land use objectives are not adequately integrated across the different legislations and plans (Alberts et al., 2017).

Despite the existence of robust legislation that govern mine closure and post-mining land use, successful mine closure remains elusive in South Africa and there continues to be a disconnect across the various legislative frameworks (Marais, 2013; Krause and Snyman, 2014; Alberts et al., 2017; Perkins et al., 2020). A number of issues have been raised by various authors around the lack of integration across the legislations, and government departments, as well as inefficiencies in assessment processes (Swart, 2003; Krause & Snyman, 2014; Alberts et al., 2017). Due to the growing awareness of the need to improve mine closure outcomes and promote more effective post-mining land use transitions, a draft National Mine Closure Strategy (NMCS) was released in May 2021 for public comment. The NMCS aims to support existing legislation and seeks to address issues around rehabilitation, planning for "a diverse post-mining economy", closure planning throughout the life cycle of a mine and a regional approach to mine closures. Additionally, the amendment to Financial Provision Regulations under the National Environmental Laws Amendment Act 2 of 2022 ("NEMLAA") came into effect on 30 June 2023 to address gaps in financial provision estimates in covering various environmental damages, progressive rehabilitation and risks associated with mining activity determined against agreed closure objectives designed to achieve an approved sustainable end state.

Mine closure practices

The disconnect between policy and legislation and the way these are applied, continue to create a complex mine closure and post-mining development space in South Africa (Watson and Olalde, 2019; Perkins et al., 2020). The focus of mine closure and rehabilitation activity continues to be on compliance (Van Druten and Bekker, 2017; Alberts et al., 2017; Perkins et al., 2020). Environmental provisions often fail to integrate with mine closure planning and financial provision guidelines across the various policy, practices and legislation (Marais, 2013; Krause & Snyman, 2014; Alberts et al., 2017). There are also concerns around the lack of consideration of socio-economic impacts and management of social risks (Stacey et al., 2010; Krause and Snyman, 2014; Ackerman et al., 2018).The consequences of ineffective mine closure in South Africa are evident from the number of abandoned mines and operations on extended care and maintenance, the divestment of mines to less well-resourced companies, and rise in illegal mining activities (Watson and Olalde, 2019). To date no large-scale mines have been granted full closure, with many remaining on care and maintenance due to a disconnect between closure planning, practice and policy (Van Druten & Bekker, 2017; Watson and Olalde, 2019).

Although there is a growing awareness of the need for active closure planning and progressive rehabilitation, in practice closure remains a complex process due to unclear roles and responsibilities and the difficulty in integrating stakeholder expectations. There is also inadequate integration of individual closure plans into regional strategies and an understatement of the significant socio-economic consequences of closure (Ackerman et al., 2018). Engagement with communities continues to mostly entail the dissemination of information rather than a collaborative process (Krause and Snyman, 2014; Ackerman et al., 2018). The draft NMCS and Financial Provision Regulations have been largely welcomed as positive steps in addressing various issues around mine closure, however concerns remain around the implementation and governance of regulations, the management of social risks and stakeholder consultation process, the integration into current legislation, as well as unclear processes and definitions around post-mining land use, amongst other things (Centre for Environmental Rights, 2021; FSE, 2021; Bega 2021).

2.3 Mine closure risks

The environmental and socio-economic risks associated with mine closure are significant and are affected by several inter-related factors, particularly the geographic location of the mine, the mineralogy of the orebody, the mining method, and the extent to which impacts have been proactively managed during the life-of-mine. The sections below provide an overview of generic post-closure impacts and risks typically associated with mining operations.

2.3.1 Environmental risk

Mining and its related activities occupy large tracts of land which is extensively and, more often than not, permanently altered through deforestation, building of infrastructure, excavation and the land-disposal of large volumes of waste such as waste rock and processing tailings. This alteration often leads to land degradation, defined by the United National Environmental Program (UNEP, 2015) as the reduction in the biological and/or economic productivity of the land, and can be either temporary or permanent. In the case of mining, this degradation is typically characterised by physical instability, soil erosion and deterioration, loss of vegetation, and increased surface water runoff and contamination. Land disturbances are, furthermore, seldom limited to either the operational period of the mine or the physical mine site. For instance, mine workings frequently disrupt the natural flow of surface and ground waters and may lower water tables in the area, an effect which is difficult to reverse. Land fracturing and subsidence due to underground mining can extend for kilometres beyond the surface footprint of a mine site and continue for decades beyond mine closure, as underground structures slowly deteriorate and collapse (Bell et al., 2001; UNECA, 2011; Zhengfu, 2010). Furthermore, as highlighted by Broadhurst et al. (2019), active discharge, seepage, run-off and dust emissions from abandoned or ineffectively rehabilitated mine workings and waste impoundments often result in extended and prolonged pollution plumes, which adversely impact on the surrounding water sources and land for decades and even centuries. Of particular concern in this regard is the formation and dispersion of acid mine drainage (AMD) due to weathering of the sulphide mineral, pyrite, a commonly occurring gangue mineral which occurs in many hard rock ores and coal deposits. AMD is typically characterised by low pH values (<6), high salinity and elevated metal concentrations and tends to form at the exposed rock faces of defunct mine workings and deposits of pyrite-bearing mine waste rock and tailings. The formation of AMD is normally highly protracted and, unless contained, can continue to be dispersed into the surrounding environment for hundreds of years, with the acidity, salts and metals impacting the quality of water sources and soils, the growth of local vegetation, and the health of living organisms, such as fish (Sarma, 2005; Simate and Ndlovu, 2014). In accordance with reports by Chadwick et al. (2013) and Simate and Ndlovu (2015), the toxicity and acidity of AMD induces severe oxidative stress and impairs osmotic balance of fish by interfering with the uptake of salts through the gill, ultimately reducing and even eliminating fish populations.

Despite the advances in rehabilitation regulations and practices around the world, effective rehabilitation of mine-degraded land and waste impoundments remains largely elusive. This is particularly common in South Africa where the avoidance of rehabilitation and mine closure responsibilities is common practice (Perkins et al., 2020; Watson and Olalde, 2019). Even in cases where rehabilitation is carried out, this may not necessarily be sufficient to eliminate the long-term risks associated with the continuous emissions from defunct mine workings and, in particular, waste piles (Godfrey, 2017; Gule, 2021). Remediation may be insufficient, incomplete or of a poor quality, while a loss of societal memory can mean that rehabilitated sites may be excavated or developed in the future, resulting in exposure of reactive material to the elements and renewed pollution (Brown Weiss, 1984). This is partly due to the fact that many of the post-closure risks, such as AMD generation, are difficult to reliably predict (van Druten and Bekker, 2017).

As noted by Andersen et al. (2014), Limpitlaw (1998) and Sakuwahu (2018), the environmental impacts of mining, including deforestation, land degradation and biodiversity losses, are not only as a direct result of resource extraction and processing activities. The infrastructure, including roads, pipelines, power facilities and ports, and human activities required to service these mines can result in significant cumulative impacts on natural resources, particularly in cases where there is extensive development in mineral-rich jurisdictions. (Andersen et al., 2014). The economic activity associated with the mines and supporting infrastructure also often results in extensive migration of people to an area and development of human settlements, posing additional risks to biodiversity and placing further burdens on local natural resources. A study by Sakuwahu (2018) found, furthermore, that the impact of community-induced land alterations in the copper mining Luanshya district in Zambia was not only extensive, it also accelerated during mine downscale periods. This is because the closure of the mines or scaling down of mine activities was associated with retrenchments and hence created a population of former mine workers and their families who previously depended on mine wages for their livelihoods and now needing alternative means. As such, there were observable increases in deforested areas in the district as more people involved themselves in charcoal production, quarrying and agriculture.

2.3.2 Socio-economic risk

The loss of employment and the displacement of livelihoods are without doubt the most critical socio-economic concerns caused by mine closures and down-scaling (Limpitlaw, 1998; Sonter et al., 2014). This is particularly the case where mining is the main source of employment and/or generator of economic activity (IDASA, 1995; Marais et al., 2017). In addition, the surrounding communities may be deprived of many essential and basic services and infrastructure in cases where these were provided by the mining companies. These is most felt in small mining towns whose social, political and economic life are completely dominated by the mine (Godsell, 2011).

However, mine closure can also have several additional and more nuanced socio-economic impacts. Disused and unrehabilitated mine shafts and dumps for instance often become a target for illegal mining activities. Whilst in many cases these activities may be driven by economic factors (Wilson, 2018), in South Africa illegal miners of defunct (and sometimes even operating) gold mines, known as “Zama Zamas”, are often heavily armed and associated with significant criminal gang activity and illicit trade. Apart from the direct safety and security risks posed by such activities, illegal mining can also adversely affect the physical stability of mine shafts and workings, exasperating the problem of subsidence. Coal waste piles in the Mpumalanga region are reportedly also being mined by informal miners, including children, for their own energy needs and as a form of income (ActionAid, 2014).

Several socio-economic risks are associated with both the environmental impacts of mining and mining-induced activities, which can affect the health, safety, quality of life and even the livelihoods of surrounding communities. Environmental pollution can result in negative health effects including exposure to harmful contaminants through inhalation, ingestion of contaminated water and food such as crops, fish and livestock, and through dermal contact (Ngole-Jeme and Fantke, 2017). Exposure to metals and semi-metals is a particularly serious consequence of mining activities, as these elements can be highly toxic at elevated concentrations and are very persistent (Duruibe et al., 2007; Hawkes, 1997; Lenntech, 2004; Morais et al., 2012). They thus tend to accumulate in sediments and soils as well as vital organs and glands, such as the heart, liver, kidney and brain, impairing function and causing varying degrees of ailments based on acute and chronic exposures (Dermirezen and Ahmet, 2006; Farooq et al., 2008). Apart from metals, dust from waste piles and contaminated land can also contain minerals such as pyrite, quartz and kaolinite which have all been linked to occupational lung disease (pneumoconiosis).

Other than health effects, contamination of soils and water can reduce the productivity of soils and have adverse effects on the viability of crops and health of livestock (Mangena and Brent, 2006). For instance, water that has come into contact with AMD has reported to pose a serious health risk for cattle and other livestock (Simate and Ndlovu, 2014). In their study to assess the cost of coal mining on agriculture and human health in Odisha, Hota and Behera (2015) found the cost incurred by the local communities, in terms of loss of agricultural production and increase in medical expenses, to be substantial. In particular, pollution of land and water by AMD arising from coal mining, resulted in a loss in livelihood from both fishing and farming. Locally, a report by the Centre for Environmental Resources (CER, 2016) has claimed that the impact of coal mining activities in Mpumalanga is in most cases so severe that farming activities cannot be sustained on the surrounding land. A study by Kootbodien et al. (2012) also found that the levels of arsenic, lead, zinc and mercury in vegetables grown in the vicinity of three different tailings facilities in the Witwatersrand basin exceeded recommended limits in all cases. The above-mentioned risks are aggravated by the fact that human settlements are often located in close vicinity to mines and waste piles. Whilst local mining regulations and international practice prohibits or avoids locating residential areas closer to 500 m from a tailings dump or mining operations (Kneen et al., 2015), these buffer zones are often not adhered to. This is particularly obvious in the Witwatersrand goldfields in South Africa, where the unrestricted encroachment of residential houses onto land close to defunct tailings storage facilities (TSFs) bears testimony to the difficulties in maintaining reasonable buffer zones between human settlements and defunct mine waste dumps in perpetuity, as well as the risks that this poses to surrounding communities as a result of exposure to windblown dust and metal pollution (IHRC, 2016). Also posing a risk to humans, as well as livestock, are the open pits, shafts and adits, which have been associated with loss in cattle, as well as death of children (DMRE, 2018a; MMSD, 2002; van Wyk, 2016).

The negative environmental impacts of mining have often led to mine company-community conflicts and have received a great level of attention by advocacy organisations and traditional and social media (Broadhurst et al., 2019). In a study on the perceptions and concerns of coal mining in the South African Mpumalanga

Province, Shongwe (2018) found that the number of incidents and conflicts relating to mining pollution from both active mining operations and defunct mine sites and waste piles is growing. Major concerns amongst participants in this study related to occupation of land, declining water quality and soil fertility, as well as land subsidence, destruction of aquatic life, loss of soil fertility, and the associated decline in crop productivity. Poor rehabilitation of both current operations and abandoned mines was, furthermore, seen to be the major contributor to environmental pollution and associated risks.

In terms of economic risks and liabilities, the costs of mitigating environmental pollution and rehabilitating contaminated mine sites are significant, with the responsibilities of legacy sites largely falling to the State. Governments, particularly in developing countries, often lack finance and human resource capacity to implement the rehabilitation of mining legacies, beyond the basic health and safety rehabilitation requirements. In the specific case of South Africa, mine closure regulations require that mining companies make financial provision for rehabilitation and closure costs. There has, however, been much criticism that this is often not sufficient to cover the costs for rehabilitation in general, and does not cover premature closure and “derelict” or “ownerless” mines, the rehabilitation of which is funded from the fiscus (Eversheds-Sutherland, 2019). Considering that there are approximately 6,000 officially listed mining legacy sites (termed ‘derelict’ and ‘ownerless’ (abandoned), this is a significant liability for the state. In 2009 it was estimated that rehabilitation would have cost approximately ZAR30 billion, excluding the long-term treatment of AMD and the construction and operating fees of plants (Auditor-General South Africa, 2009; DME, 2009). A later inventory by Unger et al. (2012), reported more than 50,000 “abandoned” (also termed “derelict”, “orphan”, “former” or “legacy” mines) mine records. This situation is not unique to South Africa. In Australia, the cost to rehabilitate some 15,000 abandoned mines in Queensland alone is estimated at AUD$1 billion (Queensland Government, 2012). Rehabilitation of mining legacies in Australia on government owned land, with a few exceptions in the Northern Territory, are the responsibility of the state and territory governments, whilst freehold landholders are deemed responsible for abandoned mines on freehold land in Queensland (Unger et al., 2015). Similarly, in Canada liabilities for abandoned mine sites is estimated at AUD$1 billion for sites under federal jurisdiction alone. In light of these costs, Unger et al. (2015) note that a resilient mining legacy management programme is one that has multiple funding sources and significantly reduces liability for the state/community.

2.4 Post-mining land use

Mining is a temporary land-use as the lifespan of a mine depends on the economic viability and availability of extractable mineral resources. Best practice mine closure planning requires land to be rehabilitated and transitioned into a post-mining land use (IRMA, 2018; ICMM, 2019; World Bank, 2021). Post-mining land use development is increasingly being recognised as an important part of addressing the economic and socio-economic impacts of mine closure (Limpitlaw and Briel, 2014; Bainton and Holcombe, 2018; Edwards and Maritz, 2019).

2.4.1 Current post-mining land use practices

Post-mining land uses encompass safe and stable landforms that can provide a habitat and/or ecosystem to support activity beyond mining. These activities and habitats may be different to those historically present on the site. The most common alternative post-mining land uses can be grouped into various categories, including agriculture, forestry, intensive recreation and non-intensive recreation as shown in Table 2.2 (Narrei and Osanloo, 2011; Mborah et al., 2016; Kivinen, 2017; Manero et al., 2020; Holcombe and Keenan, 2020).

Table 2.2 Possible alternatives for post-mining land-uses

Land use category	Specific land uses	Examples
Agriculture	Industrial crops, livestock farming, biomass crops, traditional crops, greenhouses, nursery	San Martin (Honduras)
Forestry	Lumber production, woodland, shrubs and native forestation	Jarrah Forest (Australia)
Conservation and ecosystem services	Nature reserves, protected sites, wetlands, wildlife habitats	Kebun Raya (Indonesia), Fresnillo (Mexico), Haller Park (Kenya)
Industry	Manufacturing, agro-processing, bio-refinery, land-fill	Bluewater (UK), Woodlawn (Australia)
Energy	Renewable energy (solar, wind), energy infrastructure (transmission and grid)	Kidston (Australia), Questa (USA), Emscher Park (Germany)
Water	Water supply/reservoir, ground water, surface water, aquaculture	Collieburn (Australia), Big Brown (USA)
Tourism	Museum or exhibition of mining innovations and history	Kimberley Big Hole (SA), Eden Project (UK)
Recreation	Sport field, sailing, swimming, fishing pond, hunting, park and open green space	National Coalfields (UK), Prosperstrasse (Germany)
Community & culture facilities	Heritage sites, historic sites, residential/housing, real-estate, educational facilities	Bingham Canyon (USA), Creighton (Canada)
Research facility	Research and science facilities	Kamioka (Japan)

The choice of post-mining land use is generally determined by economic, social and technical factors. There is often complexity around integrating all the influencing factors, for example the suitability of former mining sites for different post-mining land uses depends on current land use surrounding the site, infrastructure and facilities, and the extent of environmental impacts, such as soil and water contamination (Mborah et al., 2016; Kivinen, 2017; Young at al., 2019; Manero et al., 2020). Post-mining land use selection is an important aspect of mine closure planning. This is because a clear definition of the post-mining land use greatly facilitates closure planning, particularly with respect to defining the closure vision and site-specific closure objectives, as well as the selection of closure activities and the definition of success criteria (ICMM, 2019). There are several frameworks and/or tools that have been developed to support the selection of post-mining land uses, including assessing land capability (discussed in section 2.4.2). However, there continues to be a focus on environmental and mine site technical factors, with socio-economic factors and risks often underestimated (Limpitlaw and Briel, 2014; Bainton and Holcombe, 2018; Edwards and Maritz, 2019).

Transitioning mining regions and their communities into successful post-mining land use and economies remains a challenge. Conservation areas such as wildlife habitats and restoration of native vegetation and wetlands continue to be the focus of post-mining land considerations, in comparison to land uses such as agriculture and industrial activity (Limpitlaw & Briel, 2014; Mborah et al., 2016, Holcombe and Keenan, 2020). There are limited examples of mines that have transitioned into clearly defined post-mining land uses. Holcombe and Keenan (2020) find that less than 8% of mines classified as closed globally have somewhat progressed into a landform beyond mining. The few examples of large-scale mines which have been transformed into new land-uses are often in more mature mining regions such as North America, Europe and Australia. For instance, a tourist economy has been developed at the Homestake gold mine in South Dakota, which was the largest and deepest underground gold mine in North America before closing in 2002 – the mine shafts and pit infrastructure have been re-purposed to an underground national science lab, and the processing plant remodelled to a casino-resort (Deux, 2010). The post-mining alliance group through the Eden project in the UK also managed to transform a clay pit mine in Cornwall into a tourist centre which includes biomes which house a large indoor rainforest (Post Mining Alliance, 2005, 2009; Digby, 2012). On the other hand, in Australia rehabilitating the land to grasslands or restoration to pre-mining land vegetation is the common focus of post-mining land efforts as mines are often in remote areas (Maczkowiack et al., 2012; Vickers, Gillespie & Gravina, 2012). For example, in Western Australia one of the oldest large bauxite mines in Jarrahdale was successfully reforested by 2001 after ceasing operations in 1998, whereas in Queensland in Northern Australia, post-mining rehabilitation mostly focuses on the use of grass species intended for cattle grazing (Bell, 2001; Gardner & Bell, 2007; Maczkowiack et al., 2012; Lima et al., 2016; Gillespie and Gravina, 2012; Manero et al., 2020). Examples of post-closure land use in South Africa are tourist attractions or heritage sites – Kimberley big hole, Gold Reef City, Pilgrims Rest and Okiep Copper Company Museum – and residential areas such as Ebotse Golf Estate in Benoni.

In South Africa, post-mining land use selection tends to be more complex as community settlements are often near mining operations due to their reliance on mining activity for jobs, services and infrastructure amongst other things (Cao, 2007; Stacey et al., 2010; Limpitlaw and Briel, 2014; Marais et al., 2018). The socio-economic impacts of mine closure and post-mining land use such as community displacement, the disruption of livelihoods, and limitations on access to land and water resources, are often understated and underestimated (Ackerman et al., 2018; Bainton and Holcombe, 2018; Edwards and Maritz, 2019, Marais et al., 2022). Post-mining landscapes that have no definite or beneficial use identified or are restored to conservation areas often end up attracting undesirable land uses such as informal settlements (Limpitlaw and Briel, 2014). Most literature on post-mining land use currently focuses on environmental and technical aspects, in comparison to the social, cultural and political issues (Marais and Nel, 2016; Bainton and Holcombe, 2018). To achieve a sustainable post-mining land use and positive mine closure outcomes, closure and land-use planning need to be framed around land resources (i.e. physical, biological and cultural characteristics), type of mining activity, legal requirements, regional contexts, community needs, and economic, environmental, technical and social risks (Mborah et al., 2016; Kivinen, 2017; Hattingh, 2019; Manero et al., 2020). Taking these variables into account, land and infrastructure may be repurposed or integrated into local landscapes and used to create new economies.

2.4.2 Land use planning and land capability

Mining directly impacts land quality and land use, and invariably alters landscapes through activities such as vegetation cover removal, topsoil and overburden removal, water table disturbance and waste disposal. Land use planning is the assessment of land and water potential, alternatives for land use, economic and social conditions to assess suitable options for land use (ICMM, 2019). Land capability depends on the physical, chemical and biological properties of the soils, which are largely influenced by the underlying rock, climate and other factors such as slope and drainage patterns (Hattingh, 2019). All land users require a specific land capability or a set of land capabilities for successful implementation, therefore land capability is an important factor in rehabilitation and establishing suitable post-mining land uses.

It is important to differentiate between land capability, land suitability and land use. South Africa is largely a semi-arid country with very limited land capable of supporting sustainable crop production (Collett, 2013). In 2002, the national Department for Agriculture published a National Land Capability Classification (Schoeman et al., 2002) and accompanying 1:250,000 map which adapted the international concept of land capability to the South African context using a national dataset developed over 30 years. Land capability was defined as the 'total suitability for use, in an ecologically sustainable way, for crops, for grazing, for woodland and for wildlife…exclusive of social and economic variables' (Schoeman et al., 2002). The classification incorporates environmental risks and limits based on terrain (slope), soil quality and climate to classify land into eight main classes of agricultural potential as shown in Table 2.3. The crop production limitations include the choice of crop and the timing of planting, growing and harvesting but exclude low nutrient status since this can be rectified by liming and/or fertilisation. Classes I to IV constitute arable land (i.e. land that can be used for crop production), while classes V-VIII constitute non-arable land. Classes I-III represent rain-fed arable land of acceptable quality for crop production (12% of land) while Class IV represents marginal land for rain-fed crop production (13% of land). Marginal arable land is more prone to crop failures in low rainfall years (Biggs and Scholes, 2002) and requires irrigation to be sustainable in the long-term.

While land capability is based on ecological sustainability, land suitability depends on economic and social factors in addition to environmental factors. Hence an area of land can be capable of crop production but deemed suitable for urban development or mining, resulting in the reduction in the total area of arable land available as indicated above. Land use in South Africa has been recorded in the 1:250,000 National Land Cover datasets of 1994/5 (Fairbanks et al., 2000) and 2000 (Schoeman et al., 2013) which categorised land use as cultivated land, degraded land, forest plantations, urban built-up land, mines and quarries, and natural land. The accuracy of the land cover database ranges from 51% to 93% depending on the geographic area. In 2009 SANBI updated the national land cover map based on provincial studies (generated from satellite imagery), however actual values for the different categories at a national scale were not published. Most of South Africa's agricultural expansion took place before the 1960s although the threat of sanctions during the Apartheid era led the government to provide agricultural subsidies to promote food security, which in turn led to cultivation of marginal land (Biggs and Scholes, 2002). Schoeman et al. (2013) developed a national land cover change map for the period 1994 and 2005, which showed a 1.2% change in land use. Urban, forestry and mining all increased their land cover however cultivated land decreased by 0.5%. Niedertscheider et al.'s (2012) socio-ecological analysis shows that land cover in South Africa was stable from 1961 to 2006, with cropland expansion and decline and the spread of settlements and forest plantations only causing minor changes in area extent for the whole period. Land degradation is difficult to measure, however, and is likely to be underestimated.

Arable land overlaps with mineral resource rich regions, particularly in Mpumalanga and Gauteng (Ololade et al., 2017) as shown in Figure 2.6. To rehabilitate mine land and establish a land use beyond mining, soil properties (such as type, density, texture and chemistry), topographic elements of the landscape need to be considered (Hattingh, 2019). Failure to manage topsoil during rehabilitation reduces the capability of the land beyond mining (Limpitlaw and Briel, 2014; Hattingh, 2019). Due to significant alterations to the landscape by mining activity, land capability is an important aspect of addressing both environmental and socio-economic impacts (Sonter et al., 2014; Jeronimo et al., 2015; Hattingh, 2019).

Table 2.3 Land capability classes in South Africa (Schoeman et al., 2002)

Land capability class	National Land Capability Classification
I	Arable land suitable for very intensive cultivation
II	Arable land suitable for intensive cultivation
III	Arable land suitable for moderate cultivation
IV	Marginal arable land suitable for light cultivation
V	Grazing land suitable for moderate grazing, but not forestry
VI	Grazing land suitable for moderate grazing
VII	Grazing land suitable for light grazing
VIII	Wildlife

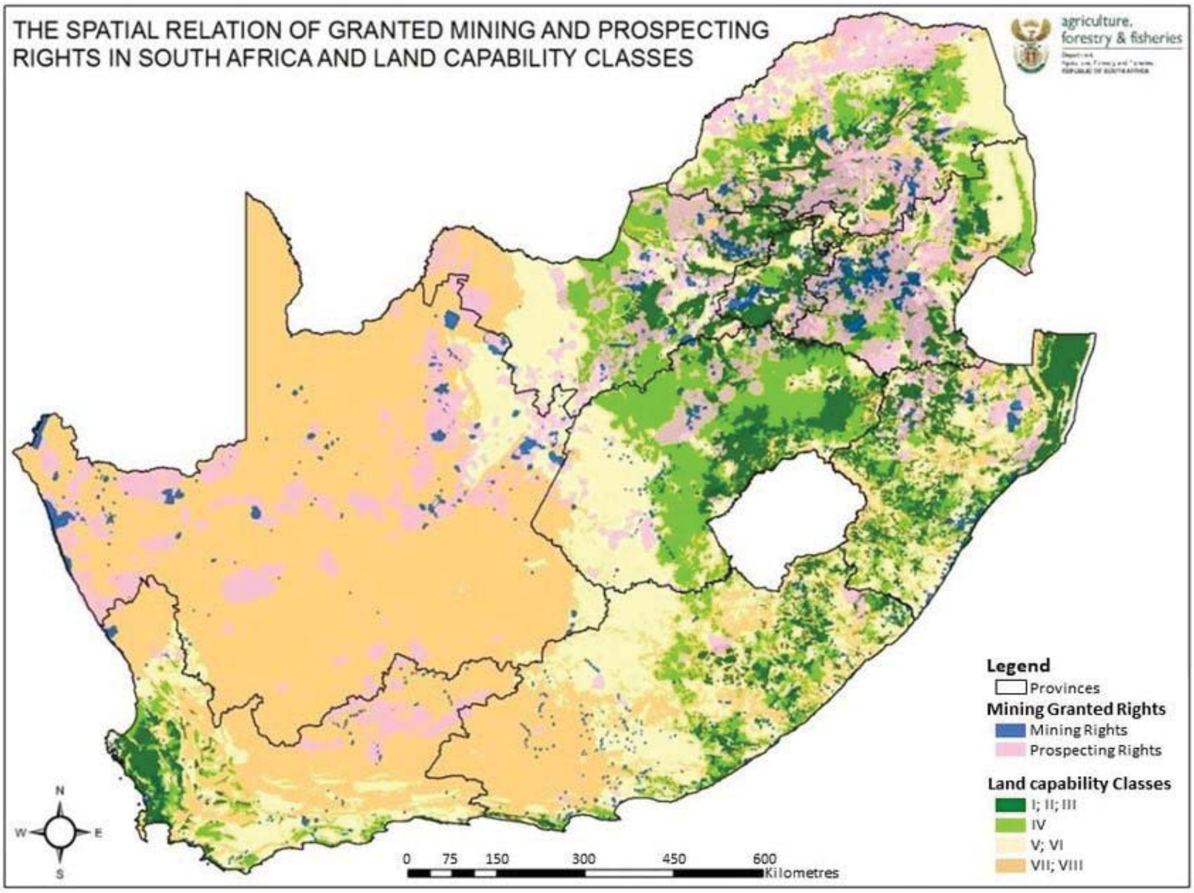


Figure 2.7 Land capability and mining rights in South Africa. Classes I, II and III are arable land; class IV is marginal arable land; class V and VI are grazing land; VII and VIII are wildlife (DAFF, 2015)

2.4.3 Land use and water

Water, energy and land are essential for human health, food security, economic growth and sustainable development and their importance is reflected in the Sustainable Development Goals, particularly SDG 2, SDG 6 and SDG 7. They are interconnected through complex natural and social systems, and policies and practices in one sector often entail consequences for the other two sectors, at a local, national or regional scale. This is becoming increasingly important as societies exceed planetary, regional and local boundaries of natural systems, and resource constraints become a limitation to socio-economic development and reducing inequalities. The interconnectedness between resource sectors makes the governance of each more challenging, as the combined risks related to water, energy and land are very difficult to predict and the complexities of governance have rapidly increased (Bhaduri, 2019 in Lawford, Pahl-Wostl & Boisvert 2019). The water-energy-land (WEL) nexus concept promotes integrated natural resources management and governance, softening the barriers between planning and decision-making processes of sector-based silos, and supports the understanding of linkages and dependencies across these sectors (Figure 2.8). It provides a basis for negotiating trade-offs and identifying measures to reduce operating costs and to enhance synergies. Due to the growing demands for land and water resources coupled with the close interlinkages among these, an integrated "nexus approach" is crucial when evaluating pathways to meet water, energy and land-related development goals (Ololade et al., 2017). The water-energy-food (WEF) nexus provides a lens through which to evaluate resource security, which is important when evaluating mining risks and post-mining development (Simpson et al., 2019). South Africa is a water-scarce country with little arable land and an energy sector dependent on local coal mining and oil imports. It is particularly vulnerable to climate change and is facing multiple resource constraints – integrated planning and nexus thinking is thus essential.

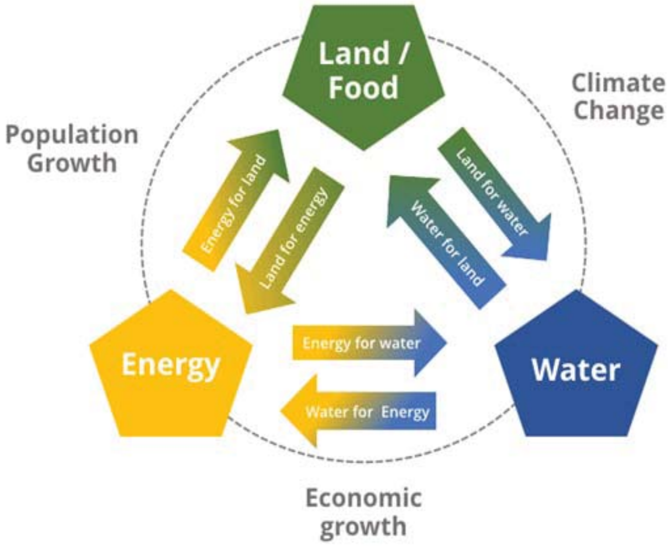


Figure 2.8 Integrated nexus approach for water, energy, and land

South Africa is a water-scarce country and is the 30th driest country in the world, with low and highly variable rainfall (both inter- and intra-annually), erratic runoff, high evaporation and shallow dam basins (DWA, 2013). Average rainfall of 490 mm per annum, approximately half of the global average (Grewar, 2019). More than 60% of its river flow arises from only 20% of the land area requiring large-scale inter-basin transfers (DWA, 2013). The South African economy primarily depends on its stored surface water resources, (including imported water from Lesotho), which contribute 76% of supply, while groundwater provides 9% and return flows (i.e. re-use) contribute 15%. Strategic Water Source Areas (SWSAs) are areas of land that either: (a) supply a disproportionate (i.e. relatively large) quantity of mean annual surface water runoff in relation to their size and so are considered nationally important; or (b) have high groundwater recharge and where the groundwater forms a nationally important resource; or (c) areas that meet both criteria (a) and (b). They include transboundary Water Source Areas that extend into Lesotho and Swaziland. They are strategically important at the national level for water and economic security for South Africa. There are 22 surface SWSAs and 37 groundwater SWSAs and cover 10% of the land surface of South Africa (Fig. 2.9) and supply 50% of South Africa’s mean annual runoff (Le Maitre et al., 2018). Changes in the quantity and quality of the water in these areas can have adverse effects on economic growth and development in the regions that they support (Le Maitre et al., 2018). Strategic groundwater water sources account for up to 42% of the baseflow in their areas and play an important role in sustaining surface water flows during the dry season (Le Maitre et al., 2018). About 24% of the settlements in South Africa that are reliant on groundwater lie within these strategic areas, equivalent to 10% of all settlements. Strategic groundwater water source areas supply about 46% of the groundwater used by agriculture and 47% of the groundwater used for industrial purposes (Le Maitre et al., 2018). Impacts on groundwater from mining activity often need to be managed for decades, after closure and are an important consideration for mine closure and post-mining development (Simpson et al., 2019).

The second National Water Resource Strategy (NWRS2) published in 2013 states that the “sustainability of the country's freshwater resources has reached a critical point” and it identifies three main challenges; security of supply (30% of towns currently are in deficit), environmental degradation and resource pollution (25% of riverine ecosystems and 48% of wetland ecosystems are critically endangered), and the inefficient use of water (25% of municipal water is physically lost). Ensuring a sustainable water balance requires a multitude of strategies, including water conservation and water demand management (WCWDM), further utilisation of groundwater, desalination, water re-use, rainwater harvesting and treated acid mine drainage (AMD).

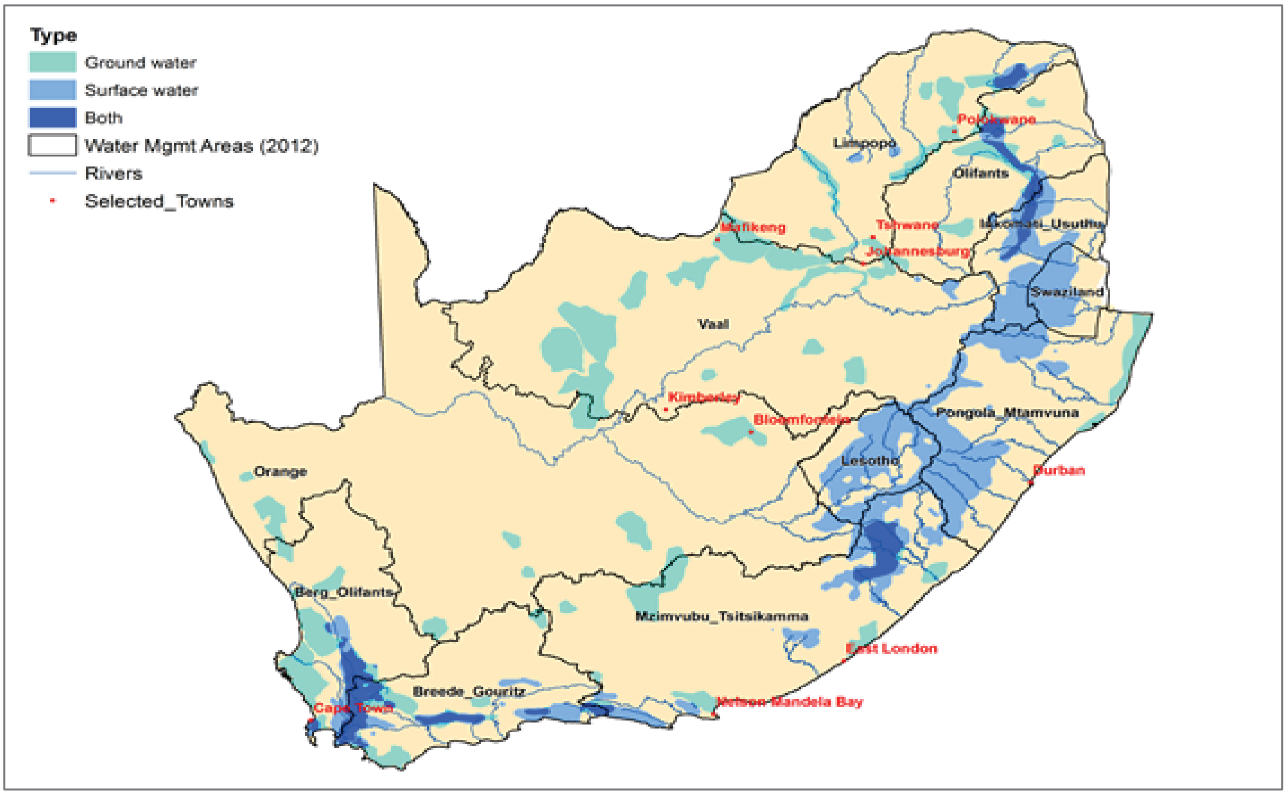


Figure 2.9 Strategic Water Source Areas in South Africa (Le Maitre et al., 2018)

2.4.4 Post-mining land use for a South African context

The South African context has the added complexity of the negative legacy that abandoned mines have left, a unique scale and diversity of mining and socio-economic contexts and residual effects of apartheid on settlement patterns and wealth distribution (Stacey et al., 2010; Marais et al., 2018). Many communities in mining areas are dependent on mining activity not only for jobs, but for services and infrastructure, leaving them vulnerable when mines close (Stacey et al., 2010). Post-mining land-use planning in the context of a developing country presents an opportunity to use mine closure as a catalyst for sustainable development (Limpitlaw and Briel, 2014; Bainton and Holcombe, 2018; Edwards and Maritz, 2019) and address the developmental goals (Fig 2.10).

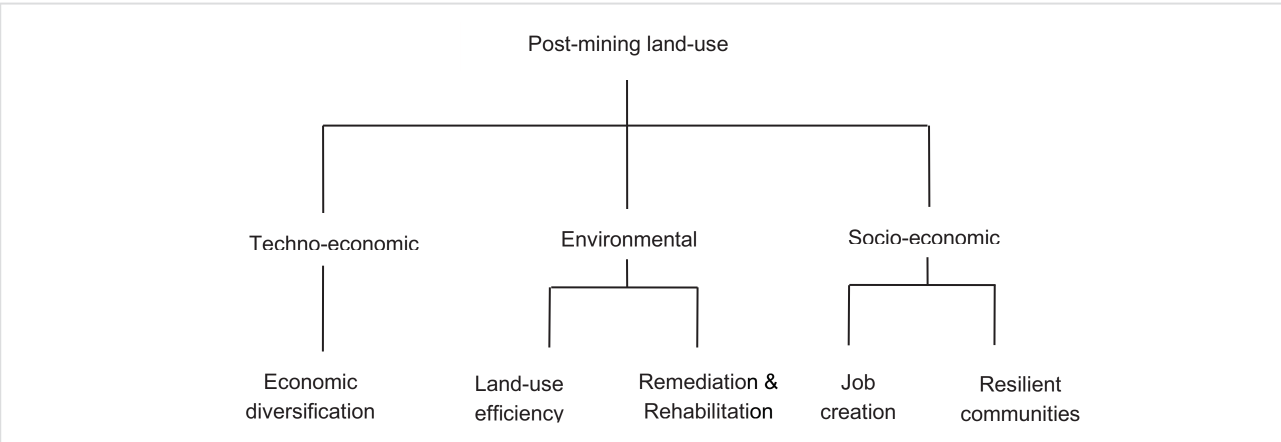


Figure 2.10 Post-mining land-use objectives in the context of a developing country (Adapted from Azapagic and Perdan, 2009)

Agriculture is a notable option for post-mining land and infrastructure use in developing countries due to its potential to promote socio-economic transition and ease the impacts of job losses (Stacey et al., 2010; IM4DC, 2014; Limpitlaw and Briel, 2014; Mborah et al., 2016; Bainton and Holcombe, 2018). The extent of environmental impacts and land degradation often limits the potential to return land to agricultural capability (Mborah et al., 2016; Kivinen, 2017). Land capability and water resource nexus need to be strongly considered to assess mine closure risks, post-mining land use options and socio-economic benefits/risks (Grewar, 2019). There are several initiatives exploring different types and scale of agriculture as an option for post-mining land use in South Africa – these include the Impact Catalyst in Limpopo, the Green Engine initiative in Mpumalanga, and the Community of Practice and Bokamoso Ba Rona projects in Gauteng. However, many such projects are still in the conceptual phase with limited insight into some of the key criteria and socio-economic risk factors around such proposed solutions.

2.5 Approaches and tools for assessing mine closure risks and opportunities

2.5.1 Overview of mine closure risk assessment approaches

Identifying and assessing risk is common across several disciplines as this provides a structured approach towards the management of stressors and/or impacts in various complex environments (Connelly et al., 2018). There is a growing awareness in sustainability research on the ability for the risk-based approaches to help to shift the focus from top-down, science-first vulnerability assessments to risk assessments that can better involve a range of stakeholders and can help to consider various risk factors (Connelly et al., 2018). Risk and opportunity assessments are increasingly being embedded in the management of many aspects of mining. There are several approaches and tools for the identification and evaluation of risks and opportunities – with wide application to environmental systems. The intention of using these tools is usually to minimize risk and maximise opportunity (ICMM, 2019).

Risk assessment and its application to mine closure have increasingly become more important in mine planning (Government of Western Australia, 2020; ICMM, 2019). Mine closure is associated with various negative impacts on society and the environment, and the risks and issues involved in mine closure are usually complex. Although environmental risks are crucial, other issues such as the safety, community, legal, financial and technical factors need to be taken into account (Laurence, 2006; Cui et al., 2020). Thus, a risk management approach is necessary to mitigate the various adverse impacts and address mine-closure issues. Closure risk approaches have significant potential to help approach and structure mine closure processes systematic manner (Cui et al., 2020). Risk assessments can be qualitative, semi-quantitative or quantitative (Government of Western Australia, 2020). The risk management standard developed by the Australian and New Zealand standard provides a framework to identify, analyse and evaluate closure risks (Fig 2.11).

Risk assessments and analysis can be performed to varying levels of detail, depending on the risks, the purpose of the analysis and the information available. For mine closure risk approaches there are however, various complexities around the scale, scope and location of the operations (Amirshenava and Osanloo, 2018; Cui et al., 2020; Government of Western Australia, 2020). The integration of socio-economic factors in mine closure risk approaches also continues to be poorly applied and understood (Government of Western Australia, 2020).

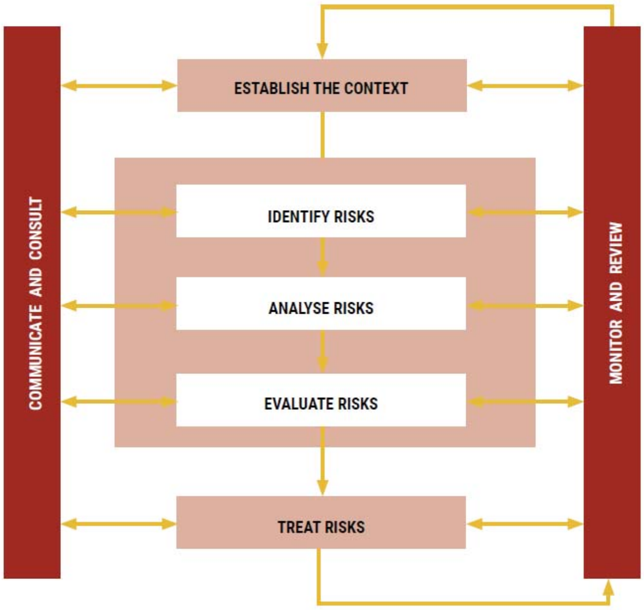


Figure 2.11 Summary risk management process (Government of Western Australia, 2020)

Mine closure in South Africa remains a challenge as many large-scale operations have officially closed and there continues to be an underestimation of socio-economic impacts of the downscaling of operations. Though globally there are several risk assessments and approaches that have been developed to address mining impacts, approaches specifically for mine closure continues to be complex, especially in the diverse socio-economic contexts such as South Africa.

Compared to the substantial body of literature detailing the socio-economic, cultural, and political impacts of mining, there are relatively few studies that specifically address the socio-economic aspects of mine closure and associated issues of planning, implementation and managing the risk factors. The implications and regional contexts of various mine closure risks are often not fully taken into account. These challenges highlight critical issues around managing closure risks to address both environmental and socio-economic factors.

To achieve more balanced mine closure outcomes, it is clear that various factors need to be considered across multi-disciplinary capabilities when modelling mine closure risks in South Africa. Factors need to be broadened to include the physical, biological and cultural characteristics of the land, ownership, type of mining activity, legal requirements, regional development, community needs, culture, economic, environmental, technical and social factors. For South Africa, there is a need for an integrated mine closure risk approach to address the range of socio-economic issues and environmental factors.

2.5.2 Overview of post-closure land use opportunities frameworks

Different decision-making tools and frameworks have been used across the literature to aid in the selection of post-closure land uses (Amirshenava and Osanloo, 2018; Arratia-Solar et al., 2022). Decision-making tools refers to the wide variety of frameworks and methodologies developed to assist in the selection of options from finite sets of alternatives according to multiple criteria, which are usually conflicting (Petrie et al., 2007; Azapagic & Perdan, 2009; Narrei and Osanloo, 2011). These tools have been applied in assessing alternative technology options in the mining industry, and other industries, based on environmental, technical, socio-economic criteria (Fourie and Brent, 2006; Petrie et al., 2007; Azapagic & Perdan, 2009; Zavadskas et al., 2016; Sitorus et al., 2019). Multi-criteria decision-making processes entail identifying the alternatives, determining the criteria for evaluating the alternatives, applying decision-making methods, ranking alternatives which then supports the selection of suitable alternatives (Narrei and Osanloo, 2011; Amirshenava and

Osanloo, 2018). Examples of decision-making methods include multiple attribute decision making (MADM), multi-criteria decision analysis (MCDA) and multiple objective decision making (MODM) (Sitorus et al., 2019). In the context of post-closure land use, decision-making tools have been used to rank post-closure land use alternatives (Narrei and Osanloo, 2011; Masoumi et al., 2014), develop decision support systems for abandoned mines (Zimmerman, 2016), integrate mine closure risks into land use selection (Amirshenava and Osanloo, 2018) and evaluate land use options (Spanidis et al., 2020). Figure 2.12 shows the decision-making process applied by Amirshenava and Osanloo (2018) which integrates mine closure risks with post-closure land use selection. Cui et al. (2020) also explored decision-making tools in the context of mine closure and suggests that mine closure risks should inform post-closure land use options. In practice, the application of multi-decision criteria frameworks to post-closure land use is often hindered by the subjective nature of criteria ranking and the methodological complexity (Manero et al., 2020; Arratia-Solar et al., 2022).

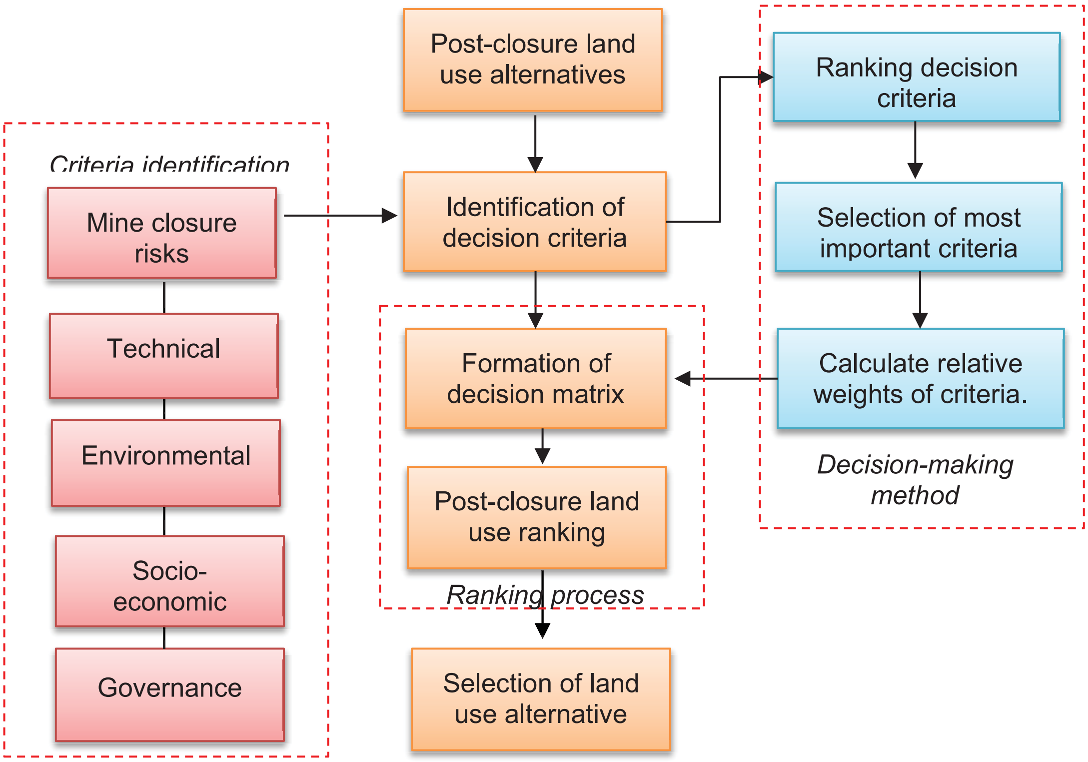


Figure 2.12 Decision-making process of integrating mine closure risks with post-closure land use selection (adapted from Amirshenava and Osanloo, 2018)

Other decision-support frameworks such as mine land suitability assessments (Amirshenava and Osanloo, 2021) and ecosystem services assessments (Rosa et al., 2018) have also been used to assess post-closure land use alternatives. Mine land suitability assessments aim to calculate the land suitability score by establishing a correlation between the influencing factors and post-closure land uses (Amirshenava and Osanloo, 2021). On the other hand, ecosystem services assessments have been used to evaluate land options based on benefits that society obtains from ecosystems (Larondelle and Haase, 2012; Rosa et al., 2018, 2019).

While there are various decision support frameworks and assessments which have been applied, selecting suitable post-closure land uses remains a complex process due to the number of factors that need to be considered (Fawcett and Laurencont, 2019; Arratia-Solar et al., 2022). Several interconnected factors need to be considered across environmental, technical, economic, social, governance and regional aspects (Amirshervana and Osanloo, 2018; 2021), as well as take into account stakeholder objectives (Everingham et al., 2018, 2020; Measham et al., 2022). Consequently, this complexity has given rise to approaches which are more semi-quantitative as some factors such as governance indicators are not always quantifiable

(Amirshervana and Osanloo; 2021). Stakeholder participatory processes are also increasingly being incorporated into post-closure land use approaches (Rosa et al., 2018; Everingham et al., 2018, 2020) due to the importance that stakeholder values play on developing post-mining economies (Everingham et al., 2020; Measham et al., 2022). More holistic approaches are also emerging which focus on post-mining land use as a developmental challenge (Kodir et al., 2017; Hattingh et al., 2019) and reframe post-mining futures as a sustainability transition (Kretschmann, 2020; Chimbganda and Broadhurst, 2023). Approaching post-closure land-use through the lens of regional development is a growing theme as areas where several mines are located face closure in the coming years (Hattingh et al., 2019; Everingham et al., 2022). In addition, the concept of sustainability pathways is particularly of interest, as it explores how developmental narratives such as economic diversification and socio-economic development can drive post-closure land use selection (Chimbganda and Broadhurst, 2023).

CHAPTER 3: CASE STUDIES ON POST MINE CLOSURE LAND USE OPPORTUNITIES

3.1 Introduction

To explore the opportunities and challenges around mine closure and post-mining development in South Africa across regional contexts, four case studies at different stages of development in key gold, coal and PGM mining areas in (Figure 3.1) were selected as summarised below:

(1) The Community of Practice project in the West Wits goldfield explored the environmental, economic and legal perspectives of the potential for fibre-crops to serve the dual purpose of rehabilitation and creating a post-mining multi-product agro-economy (resilientfutures.uct.ac.za). It was piloted in collaboration with AngloGold Ashanti and Harmony in the Carletonville area in Merafong City Local Municipality in Gauteng.

(2) The Bokamoso Ba Rona project in the West Rand and West Wits goldfields is a multi-stakeholder collaborative initiative establishing a large-scale agriculture and bio-energy industrial hub to support communities and economic development beyond mining. Sibanye-Stillwater and the Far West Rand Dolomitic Water Association have made 30,000 ha of land available land near mining operations in Carletonville and Randfontein in Gauteng. The project is expected to last 15 to 20 years and has seven partner firms.

(3) The Green Engine initiative aims to design a post-mining circular economy in the coal mining area around Emalahleni city in Mpumalanga province by forming symbiotic linkages around repurposing mine waste, renewables, bio-energy and agriculture. The project is centred around Kromdraai coal mine, part of Thungela's Khwezela colliery, but plans to collaborate with other impacted mine sites in the region to build partnerships around post-closure land use initiatives.

(4) The Impact Catalyst project in the Mogalakwena platinum mining area in Limpopo province is supporting initiatives and partnerships around agriculture, agro-processing and biofuels to promote regional post-mining development. It forms part of Anglo American Platinum (Amplats) Collaborative Regional Development programme established to address community development around its operations in Limpopo which still have significant life of mine periods. It supports partnerships with a broad range of stakeholders including community representatives, faith groups, businesses and entrepreneurs, government, academics and NGOs.

The case studies were selected to provide insight into current and emerging post-mining land use approaches and the associated contextual influencing factors. Case study analysis entailed literature review, document analysis, data collection, data analysis, interviews with key stakeholders (see Table 3.1) and engagement in workshops on the various study areas (details on the interviews and workshops are provided in Appendix A). The four case studies are described and evaluated in detail in the following sections. For each one, the context of the mine/s and communities is provided, a brief overview of social vulnerability is given, and environmental impacts and risks are described. Information on the case study's aims, objectives and planned and current projects is provided, and local economic development projects in the mining companies' SLPs are summarised. Lastly, other post-closure land use opportunities in the area are identified based on this project's research to date.

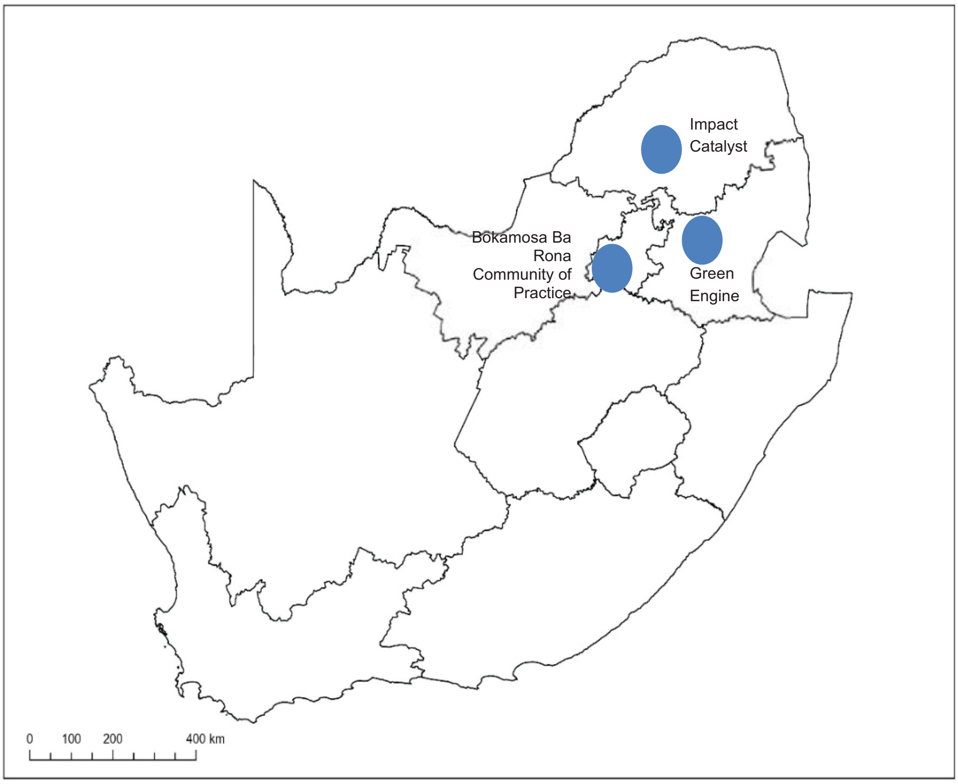


Figure 3.1 Location of the four post-closure land use case studies in South Africa

Table 3.1 Stakeholder interviews and engagement across the four case studies

Interviews	Stakeholders
Mining executive	3
Mining industry body representative	2
Community support group	4
Academia and research	3
Consultants in mine rehabilitation and post-mining development	7
Policy and legal	4
Government representative	2
Total	25
Case Study	**Workshops**
Case Study 1	7
Case Study 2	1
Case Study 3	2
Case Study 4	1
Total	11

3.2 Case study 1: Resilient Futures Community of Practice – West Wits goldfield

3.2.1 Context

The Witwatersrand Basin is the world's largest goldfield and has produced more than 52,000 tonnes of gold, more than a third of all gold globally (Tucker *et al.*, 2016). It stretches in an arc over 400 km and has seven distinct goldfields, 98 gold-bearing reefs and has been mined at over 146 mines since 1886 (Tucker *et al.*, 2016). Mining began in the West Wits goldfield, southwest of the West Rand goldfield around Randfontein, in the 1930s and now hosts the deepest mines in the world reaching depths of 4 km (Tucker *et al.*, 2016). The gold mines and processing plants of the Far West Rand are located in the highly urbanised West Rand District Municipality in the south-west corner of the Gauteng province, South Africa's industrial and financial hub. The Merafong City LM hosts Harmony's Kusasalethu and Mponeng mines and Sibanye-Stillwater's Driefontein mines while the West Rand City LM (previously Westonaria LM and Randfontein LM) hosts South Deep mine owned by Gold Fields and Kloof and Cooke mines owned by Sibanye-Stillwater (see Figure 3.2). Gold is also being extracted from old waste rock dumps by Harmony and tailings storage facilities (TSF) by Sibanye-Stillwater at Cooke and DRDGold at the Far West Gold Recoveries (FWGR). The Far West Rand has several large towns, townships and mine villages (see Figure 3.1), almost all of which were established to support the mining industry, and a significant percentage of land is owned by mining companies.

Mining has been the biggest contributor to economic activity (72% in 2014 in Westonaria LM) and employment (19% in Westonaria LM in 2014 and 25% in Merafong City LM in 2016) (StatsSA, 2016). There are over 42,000 mine employees, 83% of whom are permanent employees. More than half of permanent employees are housed in mine accommodation (single quarters, family units, company houses) and more than a third receive a living-out allowance, e.g. (Sibanye-Stillwater, 2017b, 2017a). The main labour sending areas are Gauteng, Eastern Cape, Lesotho and Mozambique, and the Eastern Cape is the focus of community development in mining company SLPs. Up to 58% of miner workers are in unskilled jobs which has a significant impact on their ability to find a job when the mine closes. All the gold doré from these mines is sent to the Rand Refinery in Germiston, which employs 421 people, most of whom are skilled (Rand Refinery, 2020).

Gold production in the West Wits has been in decline in the past decade, with production stopping abruptly at Blyvooruitzicht in 2013 due to industrial action, safety stoppages, falling gold price, increasing costs, and liquidity issues (Lawyers for Human Rights, 2017). One Driefontein shaft (No. 9) is on care and maintenance and two are undergoing closure (No. 6 and 7 shafts) while the four Cooke shafts were placed on care and maintenance in 2016/7 and closure is underway (delayed by legal challenges related to dewatering). TauTona and Savuka reached the end of their life and were closed in 2017 and 2018, with their reserves being transferred to neighbouring Mponeng mine. This resulted in a significant drop in labour force of over 20,000 workers, many of whom have moved out of mine villages (see Figure 3.3). The existing operations have a life of mine ranging from 2024 (Kusasalethu) to beyond 2106 (South Deep) as shown in Table 3.1. The most recent mine development is the acquisition of Blyvoor Gold Mine (previously Blyvooruitzicht Shaft 5) in 2016 by Blyvoor Gold to bring the underground and tailings retreatment operations back into production, and they estimate a life of mine of 50 years (Blyvoor Gold, 2020).

Gold mining in South Africa has always attracted foreign workers, with about 20% of workers in the West Wits being foreign and according to the 2011 national census, 10% of residents in the West Wits were born in other Southern African Development Community (SADC) countries. Mining also leads to internal migration from other provinces and in 2011 only 47% of residents in were born in Gauteng, while 15% were born in the Eastern Cape and 9% in the North West province (StatsSA, 2015). In the last decade, mining companies have spent over R150 million on LED projects in the West Wits and the Eastern Cape.

Table 3.2 Summary of mines and employees in the Far West Rand (Cole and Broadhurst, 2022)

Company	Mines	Processing plants	Permanent employees	Contractors	Life of Mine
Harmony	Kusasalethu (twin shafts)	Kusasalethu	3,764	496	2024 (2 years)
	Mponeng (1 shaft)	Mponeng	4,650	658	2028 (6 years)
Sibanye-Stillwater	Driefontein (5 shafts)	Driefontein 1	10,941	2,141	2030 (8 years)
	Kloof (5 shafts, 1 waste rock dump)	Kloof 1 Kloof 2	9,858	1,438	2033 (11 years)
	Cooke (1 TSF)	Cooke	846	60	2023 (1 years)
DRDGold	Far West Gold Recoveries (1 TSF)	Driefontein 2	~318	~613	2040 (18 years)
Gold Fields	South Deep (twin shaft, 1 TSF)	South Deep	2,342	1,801	2106 (84 years)
Blyvoor Gold	Blyvoor (1 shaft, 1 TSF)	Blyvoor	600	0	2061 (49 years)
Total			33,319	7,207	182 years

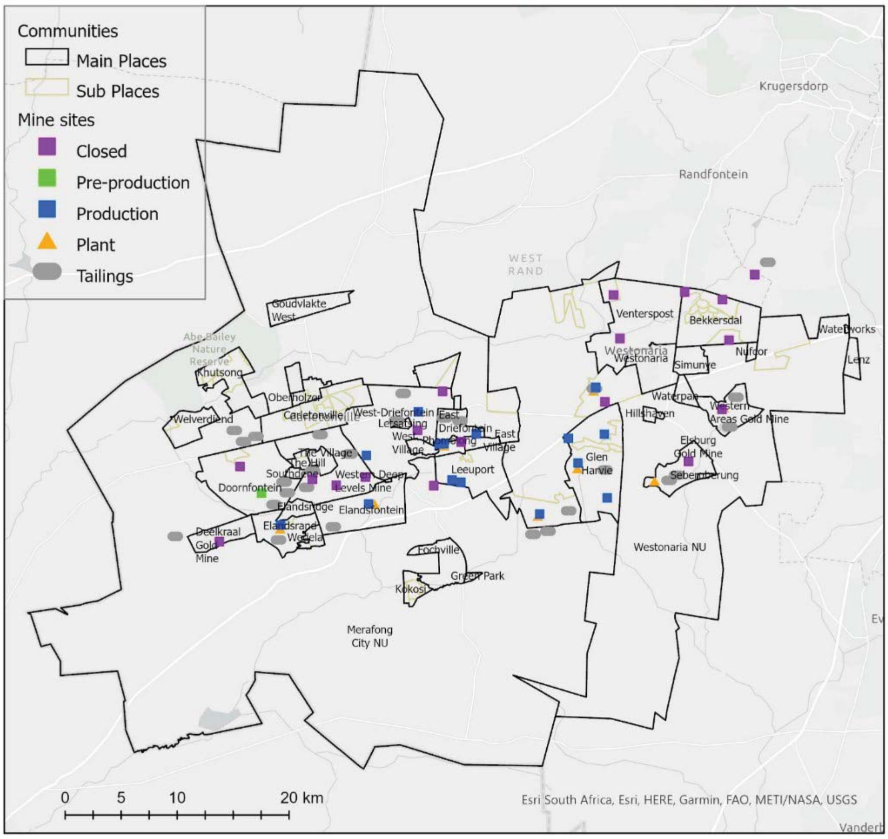


Figure 3.2 Map of the West Wits case study area (Cole and Broadhurst, 2022)

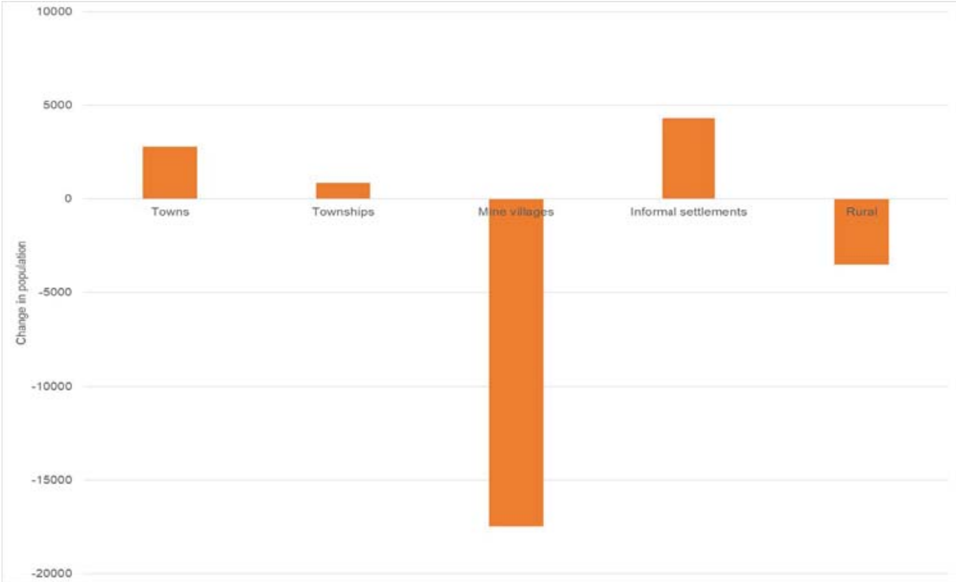


Figure 3.3 Change in population in Merafong City Local Municipality from 2001 to 2011

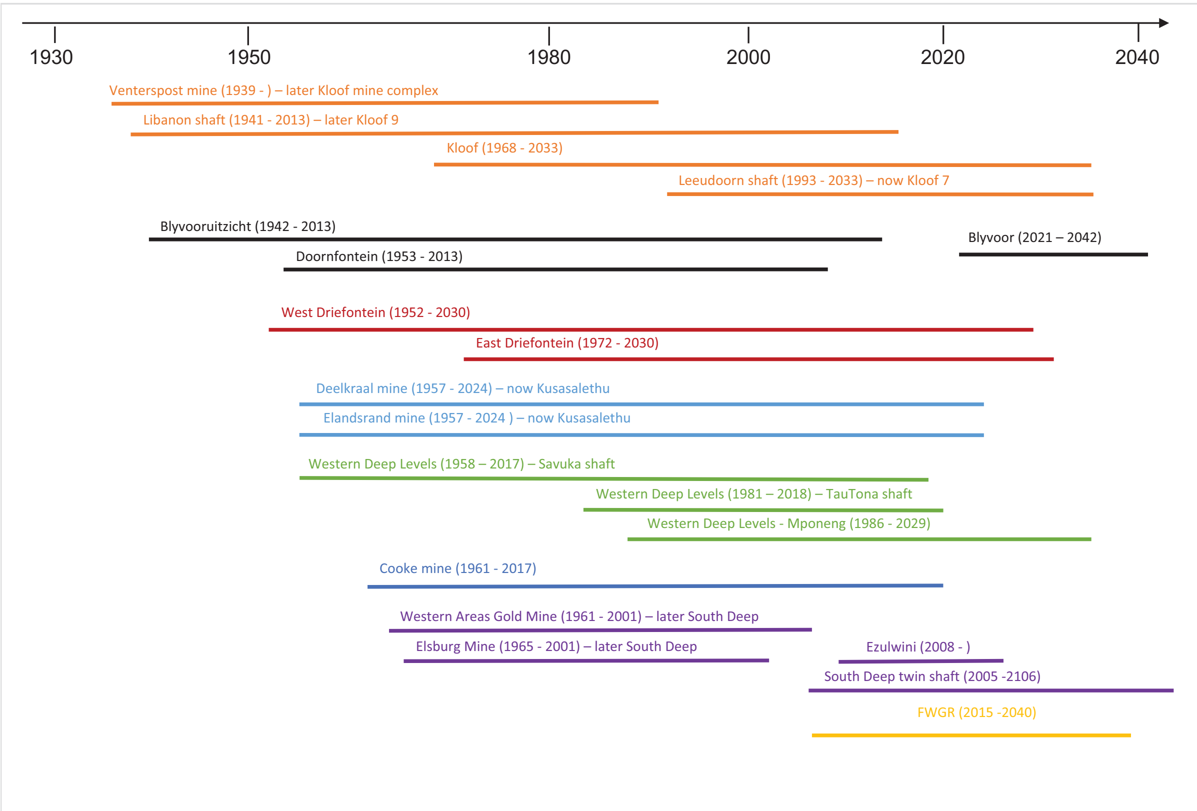


Figure 3.4 Timeline of gold mines operating in the Far West Rand (Cole and Broadhurst, 2022)

3.2.2 Social vulnerability

Diverse communities exist in the Far West Rand where most people live in towns, townships and mine villages (Table 3.3). Seven small towns (Carletonville, Oberholzer, Blybank, Welverdiend, Fochville, Westonaria, Venterspost) have the highest percentage of white people (43%), the historically advantaged population, and house 17% of the population. Six townships (Khutsong, Wedela, Kokosi, Greenspark, Bekkersdal, Simunye) are home to almost half the population. The 22 mine villages (Doornfontein, Western Deep Levels villages, Driefontein villages, Elandsrand, Deelkraal, Kloof villages, Panvlak, Cooke) are located closest to the mines and are still male dominated (73%) as they accommodate mine workers and some of their families in mine houses, single quarters or hostel accommodation. Almost 12% of the Far West Rand population live in informal settlements which grew as people came seeking work on the mines (Liefferink *et al.*, 2017). There are two small industrial areas – Nufcor and Lenz, and five rural farming communities. The towns have the highest levels of well-being (Table 3.4 and Figure 3.5), followed by the mine villages. Rural areas and townships have similar well-being and are much better off than the industrial areas and informal settlements. Overall there is significant variation between different types of communities, a legacy of Apartheid and the inability of the current government to create enough jobs and housing to meet the growing demand. There are large differences between individual socio-economic indicators, with education and internet access having the lowest levels. This is consistent with other local municipalities that host operating mines in South Africa, and South Africa as a whole (Cole and Broadhurst, 2021).

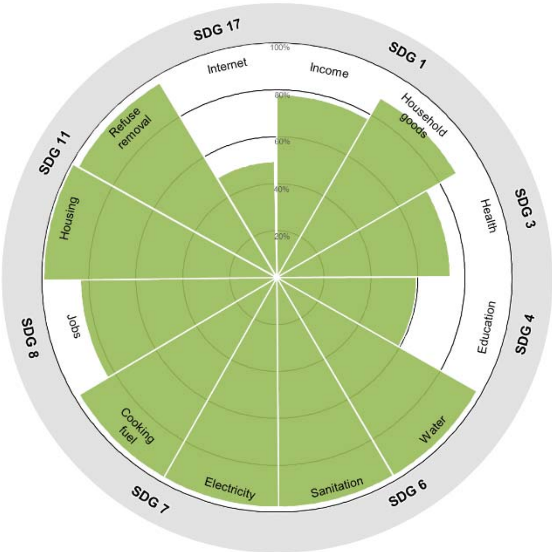
Table 3.3 Summary of communities in the Far West Rand in 2011 (Cole and Broadhurst, 2022)

Types of community	Number of communities	Population		Gender (% Male)	Race (% non-white)
		people	%		
Towns	7	52,133	16.9	49.8	57.2
Townships	6	147,418	47.7	49.0	99.8
Mine villages	22	56,810	18.4	73.2	90.3
Informal settlements	4	35,973	11.6	53.7	99.6
Industrial areas	2	561	0.2	53.9	77.1
Farming	5	16,408	5.3	54.2	92.1
TOTAL	47	309,303	100	54.4	89.9

Table 3.4 Summary of socio-economic indicators of communities in the Far West Rand

SDG	Indicator	Far West Rand	Towns	Townships	Mine villages	Informal settlements	Industrial areas	Farms
1	Annual household income (% above R19,600/year)	60.6	78.0	49.8	85.9	34.6	78.9	63.6
	Household goods (% fridge ownership)	54.6	88.3	63.1	45.9	6.9	42.9	58.3
3	Health (% without disability)	70.4	73.8	67.1	74.5	73.6	65.6	69.3
4	Education (% with Grade 12 or above)	33.1	59.5	28.8	29.7	15.6	27.4	33.8
6	Water access (% piped water in home or yard)	80.0	97.9	86.8	95.3	4.8	63.8	84.9
	Sanitation (% access to toilet)	79.2	97.8	86.6	95.7	7.8	46.6	83.4
7	Electricity access (%)	79.5	97.9	84.6	96.2	10.6	58.1	84.2
	Clean cooking fuel (%)	76.7	97.8	79.5	95.4	8.4	58.8	79.1
8	Employment (% labour force)	69.6	83.6	55.5	89.6	54.3	78.2	71.2
	Youth unemployment (% labour force)	57.9	71.5	48.9	76.2	51.6	53.1	61.0
11	Formal housing (%)	74.8	99.2	74.7	94.3	13.9	77.4	82.6
	Refuse removal (% municipal)	79.3	96.9	81.9	95.2	41.4	9.8	79.4

17	Internet access (% households)	27.3	49.6	28.2	21.6	10.3	21.4	28.4
Overall score (average)		6.5	8.5	6.6	7.7	2.4	5.2	6.8



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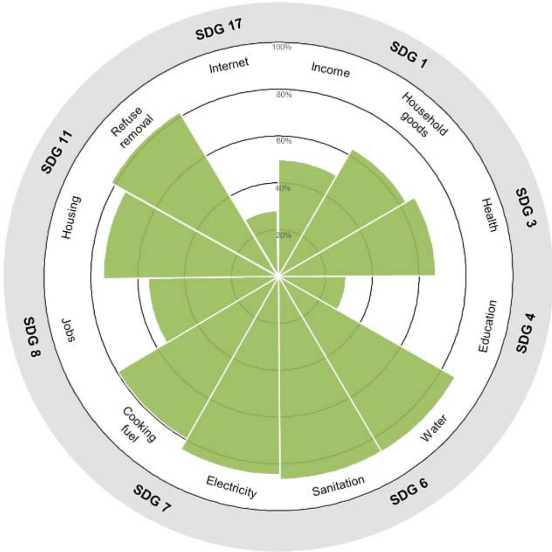

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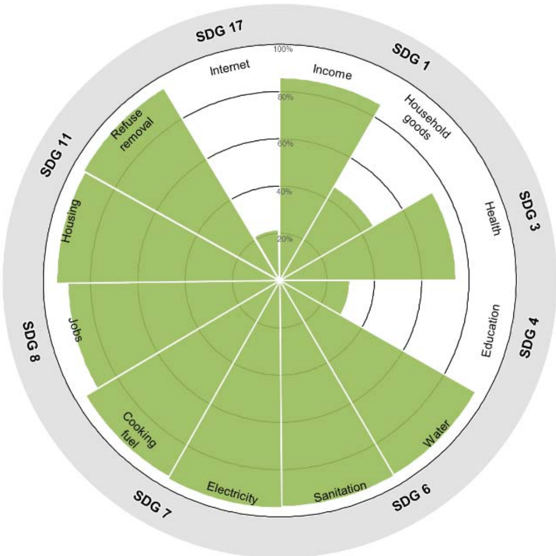

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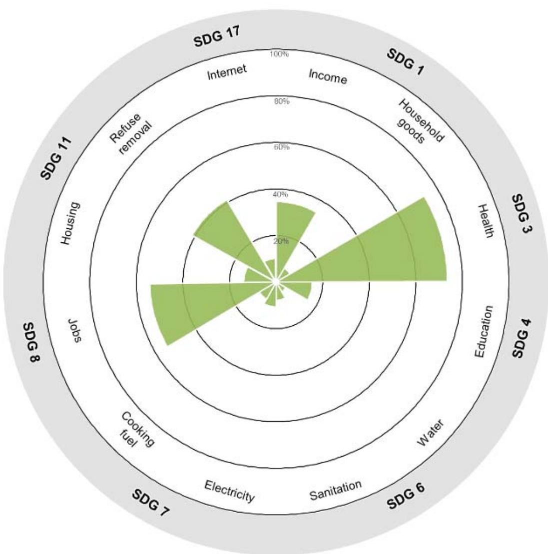

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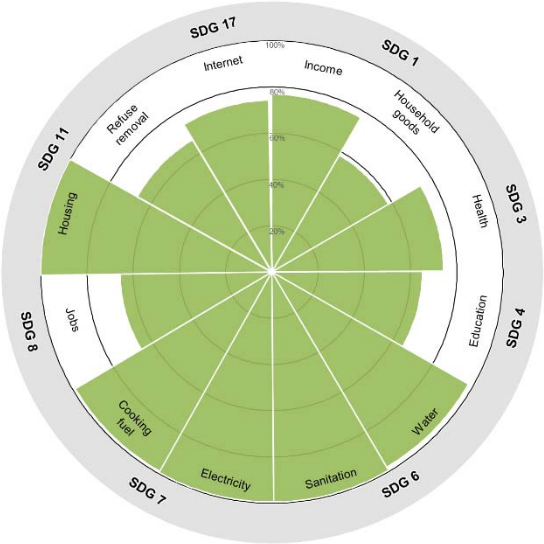

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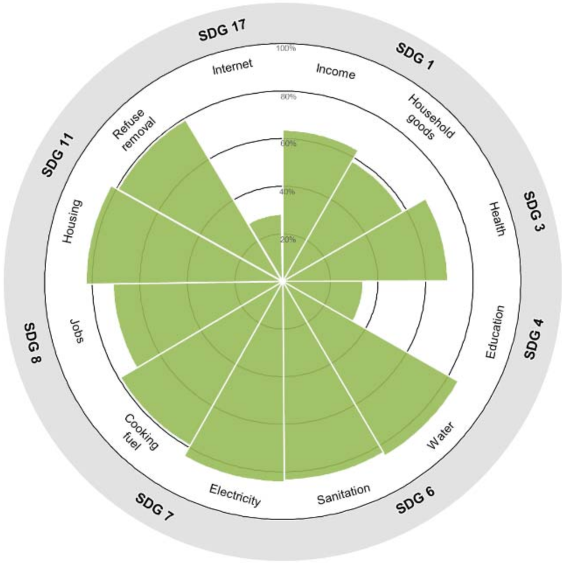

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Figure 3.5 SDG barometers for the Far West Rand a) towns, b) townships, c) mine villages, d) informal settlements, e) industrial areas, and f) rural areas (Cole and Broadhurst, 2022)

3.2.3 Environmental impacts and risks

Land

The National Land Cover Map of 2020 shows that about a quarter of the land in the West Wits is used for agricultural activities, with small areas used for plantations and only a fraction of the original land vegetation still in place (Figure 3.6). Mining and residential areas dominate the central portion of the Merafong City LM and old Westonaria LM. The area has dolomitic land in the areas of Khutsong and Carletonville, which perpetuates the formation of sinkholes and negatively impacts on water infrastructure, causing shutdowns and decommissioning of reservoirs. This is discussed in more detail in case study 2.

About two thirds of the municipal area is high potential and moderate potential arable land – land capability classes II and III – while one third is non-arable land suited for grazing or wildlife (see Figure 3.7). There are numerous mines situated on the high potential arable land, preventing agricultural activities on their lease areas. This land presents an excellent opportunity for post-closure land use if the soil is not contaminated by mining activities.

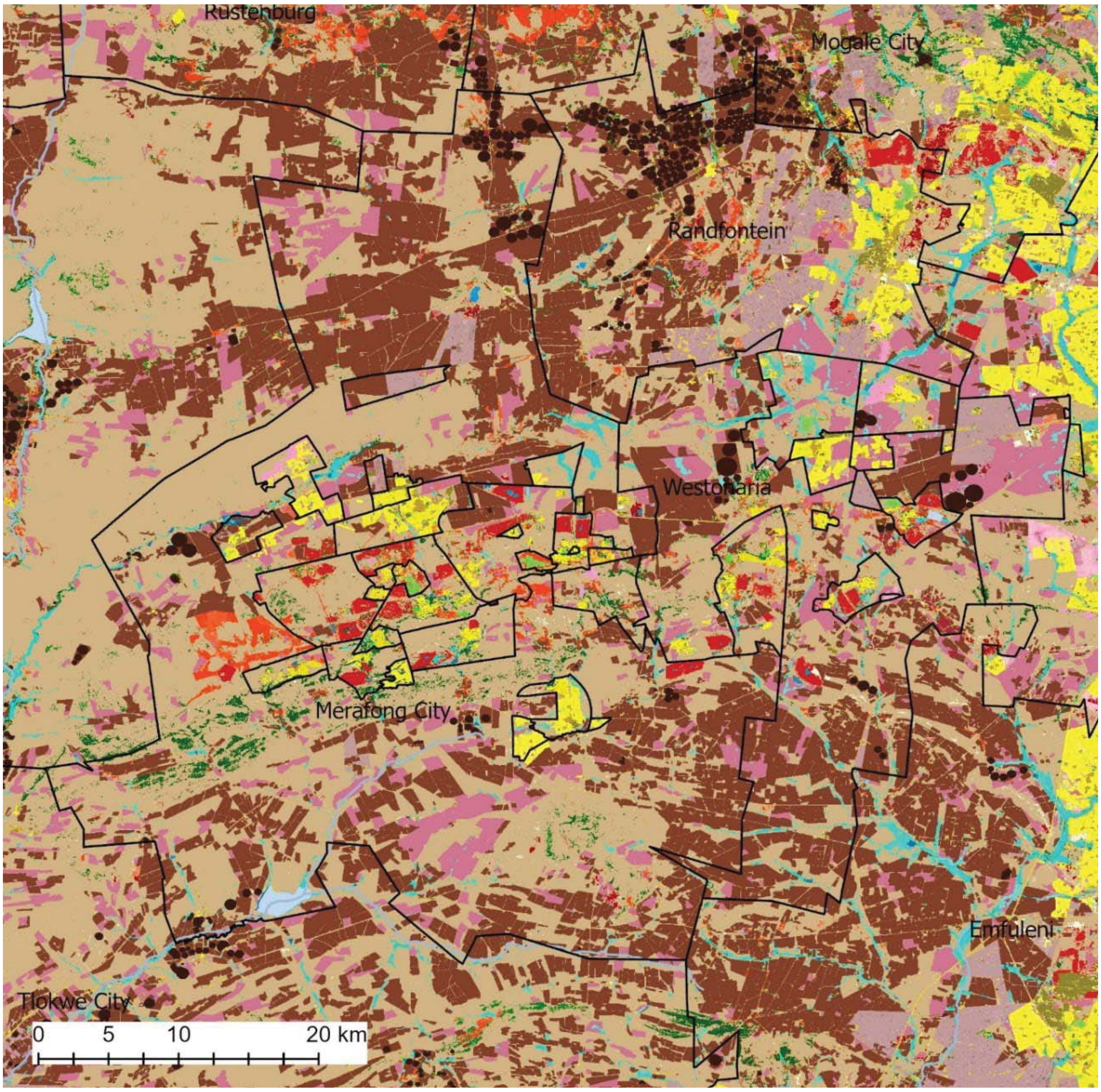


Figure 3.6 Land cover in the West Rand showing mining areas (red), residential areas (yellow), agriculture (purple and brown), forest and woodland (green) and plantations (orange) (source: National Land Cover Map 2020)

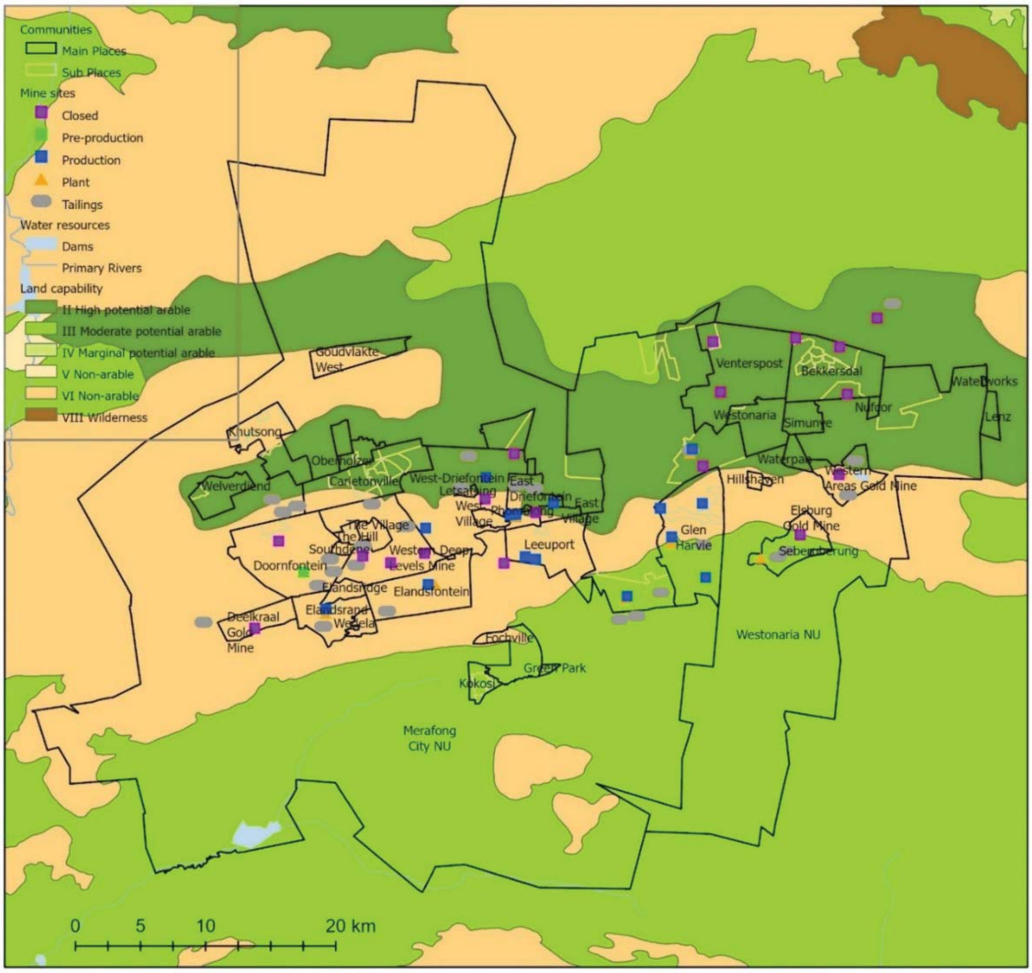


Figure 3.7 Land capability and water resources in the West Wits

Water

The Far West Rand is situated in the Upper Vaal Water Management Area (WMA) and quaternary catchments C230 and C22A. It lies over a groundwater Strategic Water Source Area (SWSA) – the Far West Karst Region (Figure 3.8) which is 138,207 ha in area (Le Maitre et al., 2018). Tension faults cutting through dolomite aquifers overlying mining areas has led to significant flooding of mine workings in the past and large sinkholes, particularly around Ventersdorp (Coussens and Garrett, 1969). This water has to be pumped out of the mines. For example, Kusasalethu discharges an average of 1.5 Ml per day of fissure water (Harmony, 2021). Water is supplied to the communities and mines by the Rand Water Board which sources its water from the Integrated Vaal River System, which is under severe pressure and water restrictions have been imposed in recent years. In 2020, Sibanye-Stillwater purchased 1,008 ML for Cooke, 343 ML for Driefontein and 4,037 Ml for Kloof, but is moving towards water independence through boreholes and wastewater treatment plants on-site (Sibanye-Stillwater, 2021).

A major problem with mine closure in the Witwatersrand area is that the mining company stops pumping out mine water ingress, which leads to mine voids becoming flooded and mine water flowing out to the surface. Chemical and geochemical reactions between the mine rock strata, wastes and oxygen, cause the water to become acidic, with elevated concentrations of salts, heavy metals and radionuclides. The major risks from the subsequent acid mine drainage (AMD) are devastating ecological impacts, flooding in urban areas, seismic activity causing safety risks, groundwater pollution, and flooding of neighbouring operational mines, impacting on economic viability of these operations (Council for Geoscience ,2010).

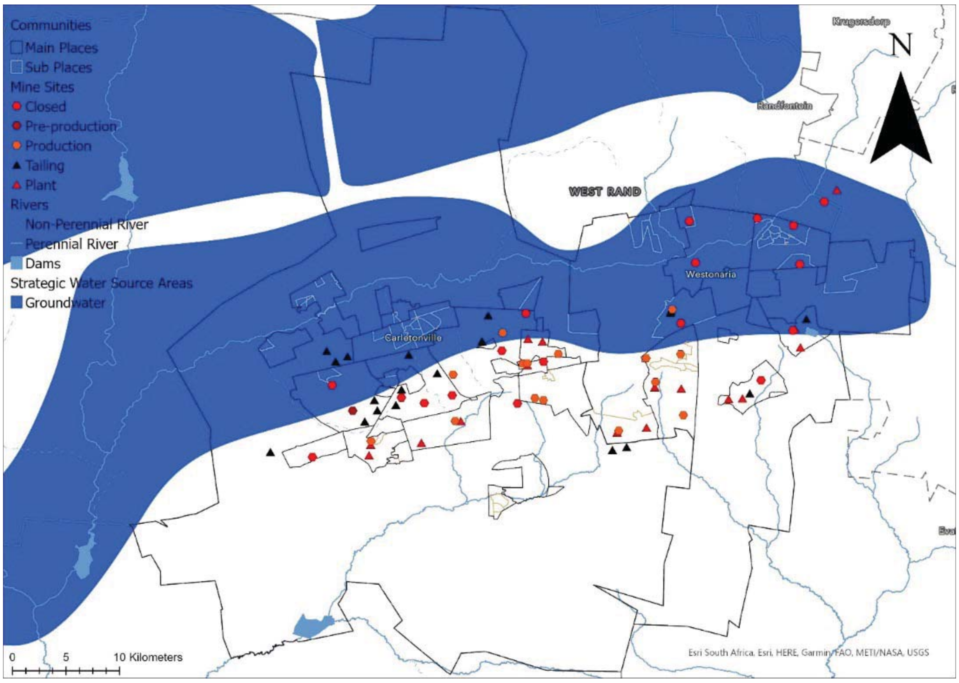
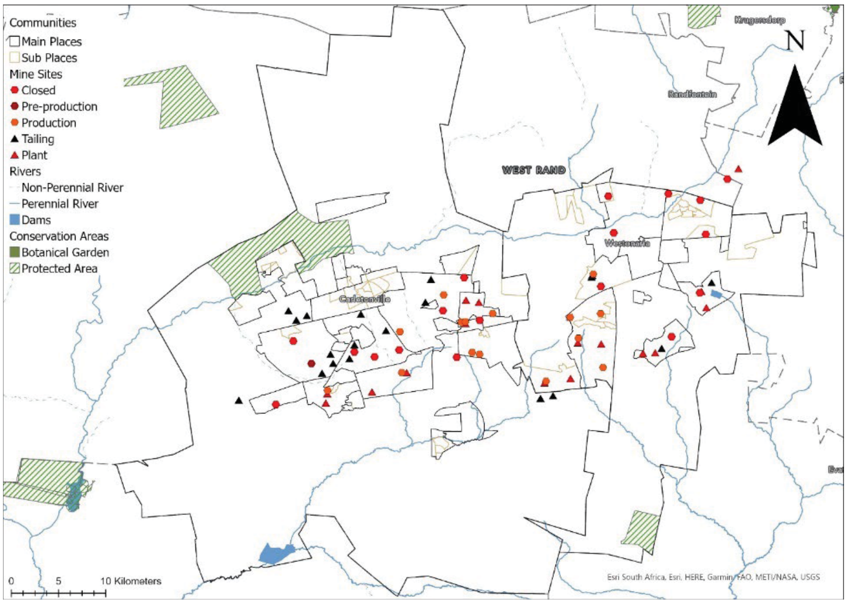


Figure 3.8 Strategic Water Source Areas, rivers and dams in the West Wits

Biodiversity

There are no critically endangered or endangered terrestrial species in the case study area (NBA, 2018). There is one formal protected area[1] in the case study area – the Abe Bailey Nature Reserve north-west of Khutsong (Figure 3.9) and one conservation area to the south-east corner of the local municipality, Tweefontein Private Nature Reserve.



[1] protected areas are areas set aside primarily for nature and biodiversity, while conservation areas are areas of conservation importance where other land uses may also be permitted

Figure 3.9 Protected areas in the West Wits

Air quality

There are no South African Air Quality Information System (SAAQIS) monitoring stations managed by DFFE in the study area as it is not considered an area of concern. This will be discussed in more detail in the following case study on the West Rand District.

Waste

There are 23 tailings storage facilities (TSFs) in the area (see Figure 3.2). This will be discussed in more detail in the following case study on the West Rand District.

3.2.4 Land use opportunities

Community of Practice Resilient Futures project

The Community of Practice (COP) project was a multi-disciplinary research study at the University of Cape Town aimed at investigating the potential for mine land in South Africa to be transformed into a restorative agricultural sector and a dynamic post-mining economy. The project commenced in 2018, bringing together expertise from Minerals to Metals, Mineral Law in Africa, the Development Policy Research Unit and the Centre for Bio-processing Engineering at the University of Cape Town. The project focused on fibre-producing crops due to their potential to promote economic diversification through multi-product value chains and bio-remediate land by absorbing metals from soil (Pandey, Bajpai & Singh, 2016; Yadav et al., 2018; Broadhurst et al., 2019; Harrison et al., 2019).

Fibre plants for a South African post-mining context

The common fibre plants grown on South African soil, were reviewed for their ability to grow on the selected degraded mine land. The two primary parameters selected were the annual rainfall requirement and temperature tolerance. Plants thriving in hot climates and requiring significant amounts of water were not chosen. The selected plants (Table 3.5) were the bast fibre crops hemp, kenaf and flax, the leaf crop sisal and the grass/bamboo crop. The two bamboo species most suited for South Africa are Dendrocalamus Asper and Bambusa Balcooa, since they are non-invasive and will not spread more than 1.5 m (The Biomass Corporation, 2008). However, Bambusa Balcooa was selected since, although requiring more water than other selected fibre plants, its water intensity is significantly less than that of Dendrocalamus Asper.

Table 3.5 Growth parameters for fibre-rich plants in South Africa (adapted from Harrison et al., 2019)

Growth parameters	*Bambusa Balcooa*	Hemp	Kenaf	Flax	Sisal
Annual rainfall requirement (mm)	700-4500	350-4000	450-3000	250-1300	500-1800
Temperature tolerance (°C)	9-35	6-32	10-35	5-30	10-45
Soil pH	4.5-7.5	4.5-8.2	4.3-8.2	5.5 7	5.5-8
Harvest time	5-6 years	90-170 days	100-240 days	80-180 days	2-4 years
Dry biomass productivity (tons/ha)	20-40	10-20	15-25	3-4.5	13-17
Fibre yield per season (tons/ha)	12-18	2.2-8.1	5-10	1-2	4

The review of fibre plant suitable for South Africa showed that bamboo, kenaf and hemp, have the highest potential based on their growth compatibility and their higher biomass and fibre yield, and potential to produce a wide-range of semi-fabricated and higher-end products (such as textiles, paper, furnishings, building materials, bio-plastics and bio-composites) as well as energy (Broadhurst et al., 2019; Harrison et al., 2019).

Conceptualising a fibrous post-mining industrial economy

The study further demonstrated the potential for fibre-crops to spur industrial development through simultaneous multi-stage processing as shown in the conceptual flow sheet in Figure 3.10. Typically, fibre plants that fall under the same classification have similar product profiles and are processed similarly, albeit specific plant characteristics result in different product properties and relative yields. Hemp and kenaf are both classified as bast fibre plants, and present similar opportunity for post-mining industrial development. A simplified flow diagram of the main processing stages for the simultaneous generation of products from bast fibre plants is given in Figure 3.11. The major stages are harvesting, pre-treatment, fibre recovery and conversion to end-products (Sponner et al., 2005; Amaducci and Gusovius, 2010; Chen and Liu, 2010; Papadopoulou et al., 2015).

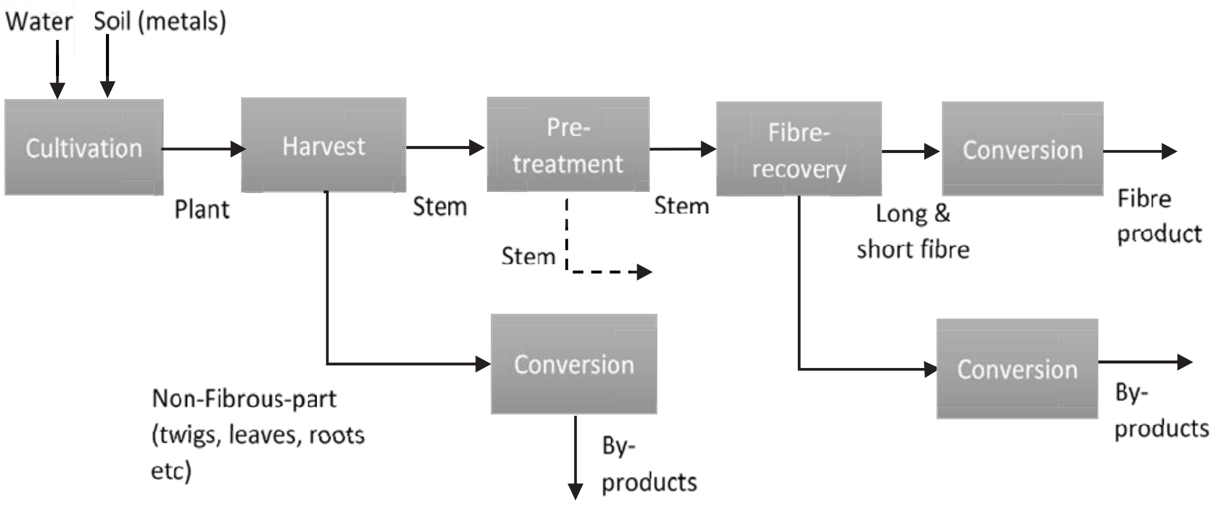


Figure 3.10 Conceptual processing flow sheet for fibre producing crops (Broadhurst et al., 2019).

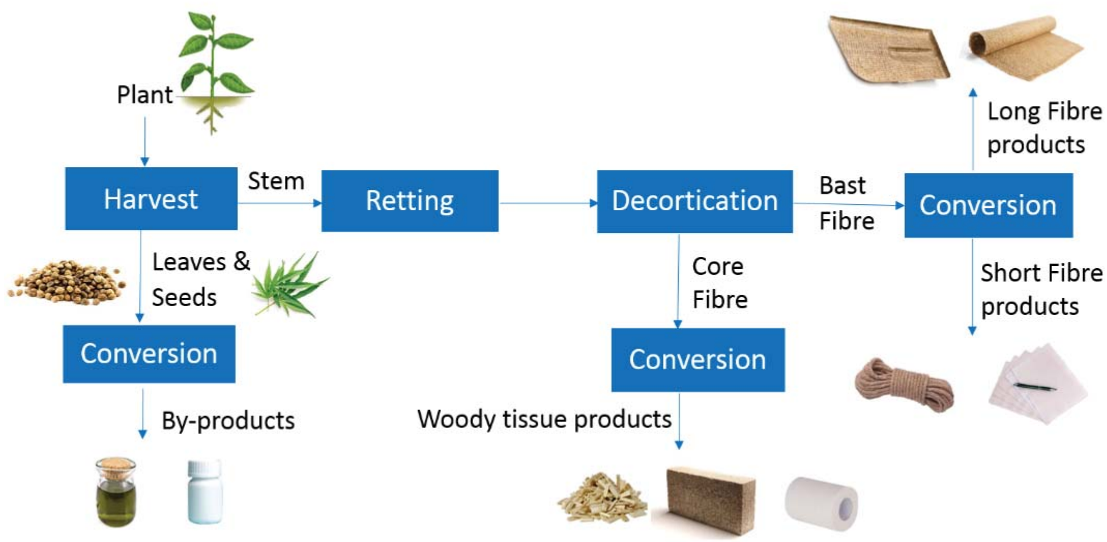


Figure 3.11 Main stages for bast fibre separation and processing (Broadhurst et al., 2019)

Although hemp and kenaf have very similar product profiles and processing, the ratio of bast fibre in the stem, fibre length and strength varies resulting in different product properties. For example, the longer length of hemp fibres makes it more suitable for conventional textiles, while the higher bast fibre content in kenaf results in a higher fibre yield. In the case of the woody grass bamboo, products are mainly generated from the stem, also known as the culm. These can be grouped as fibre-based products (including natural and "rayon" or regenerated cellulose fibre products for textiles and polymer composites), wood-based products (including natural wood and wood products for construction, furnishings and sporting equipment) and bulk processed products, such as energy and paper. Similarly, for bamboo plants, the separation of the woody tissue, fibrous and non-fibrous parts typically occur in a number of stages, shown in Figure 3.12 (Khalil et al., 2012; Rocky and Thompson, 2018). The whole bamboo plant can be converted to energy products. Alternatively, the bamboo culm, twigs, leaves and other parts can be converted into various products. The bamboo culm can be split into strips to either recover fibre (using similar processes to bast fibre recovery), or produce lumber/board products, or the culm can be used as whole "bamboo poles".

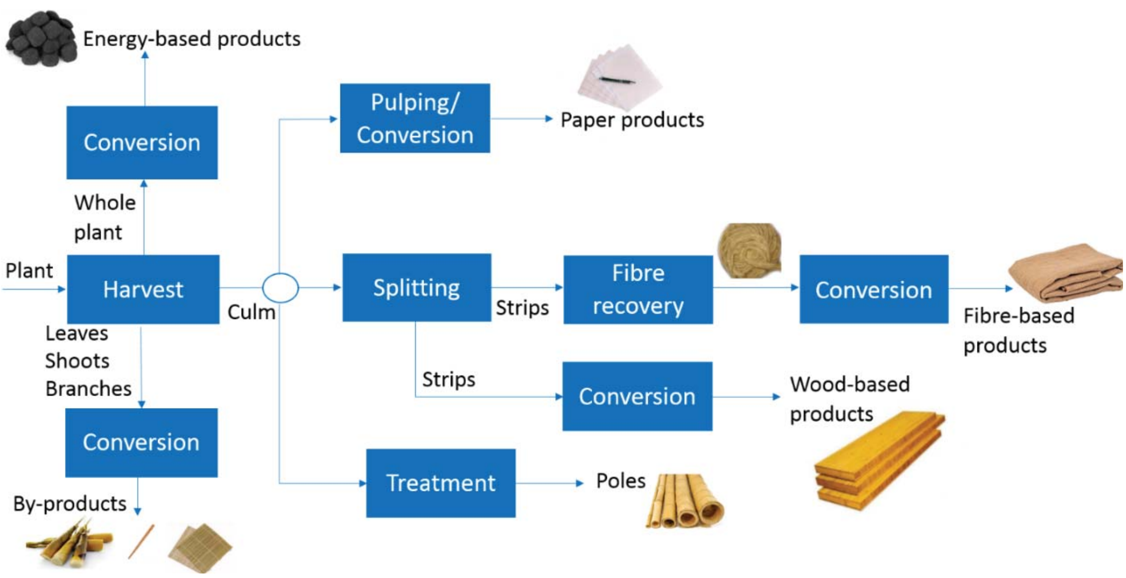


Figure 3.12 The main stages for bamboo separation and processing (Broadhurst et al., 2019)

Due to its woody nature bamboo was shown to present higher potential as a replacement for conventional timber in the production of functional products such as wooden flooring and construction materials and paper. However, the structure of bamboo limits its multi-product potential, the fibres are embedded within a matrix in the stem/culm, wood-based and fibre-based products cannot be generated simultaneously as the culm needs to go through intensive processing to recover the fibre, therefore either one product or the other can be produced (Phong *et al.*, 2011; Kaur *et al.*, 2013; Zakikhani *et al.*, 2014; Rocky and Thompson, 2018). The findings suggest that bast fibre plants are the better downstream option for the production of "green" textiles and high-end niche products such as fibre reinforced composites for the aeronautical and automotive industries. Bast fibre plants offer more flexibility in terms of processing and product options than bamboo.

In terms of phytoremediation potential, the findings indicated the potential for fibre plants to accumulate several metals typically occurring in mining regions within South Africa, particularly lead, copper and zinc (Harrison et al., 2019). These metals were shown to accumulate mainly in the non-fibrous part of the plant (Angelova et al., 2004; Meera and Agamuthu, 2012; Arbaoui et al., 2013, 2014). However, both the yield and quality of fibre products may be compromised in regions with elevated levels of metal contamination. In such cases, a two-stage approach may be more beneficial whereby hyperaccumulators are used to remediate contaminated land prior to the cultivation of fibre plants. Therefore, site contamination is a key risk factor in determining success, since high concentrations of heavy metals in the soil may affect both plant growth and fibre quality. Further site-specific studies were therefore conducted in the Harmony pilot project phase to understand the growth risk factors/parameters of the various plants.

Harmony fibre plant pilot-project

In the pilot phase 15 potential sites (Figure 3.13) were identified which could be used as pilot planting sites. These sites were subsequently narrowed down to five sites for preliminary planting, based on opportunities and risks described in Table 3.5. Bamboo and kenaf species were selected for Phase 1 of the initial 18-month trial due to their suitability for the planting areas, growth periods and availability of the respective plant species. Bamboo was planted on areas with water run-off (site 2) and tailings storage facilities (sites 2, 4 and 15). Kenaf is a lower water demanding crop and it was planted on less contaminated areas (site 1 and 13) as well on site 4 due to its high pH tolerance. Hemp was also considered for the trial, however due to regulatory issues at the time the trial did not include hemp.

The planting trials started in late 2020, three bamboo species were procured from Hortus Capensis, specifically *Bambusa balcooa, Dendrocalamus asper and Phyllostachys humilis*, as they are classified as non-invasive for South Africa. Kenaf seeds were obtained from the Agricultural Research Council. The respective sites were prepared, organic fertilisers and insecticides were added to the soil mixtures.

Initial observations of the plant growth showed positive results for bamboo at site 2, however bamboo at site 15 did not perform well due to issues with insects. Kenaf at site 1 and 13 showed good growth. Both kenaf and bamboo at site 4 showed very poor growth, largely due to the high contamination of the site owning to a prior tailings spill. The initial planting trial progressed well in the early stages and provided learnings on the challenges around planting in different sites. However, the project initially started as part of an Anglo Gold Ashanti initiative and was subsequently handed over to Harmony, following Harmony's acquisition of AngloGold Ashanti's assets in late 2020 and upon the review and consolidation of operations, the fibre pilot initiative was suspended. As a result, the plant sites have been largely unsupervised, despite that, the plants at the sites which showed early positive results showed resilience and continued to grow.

The next phase of this work would need to assess the contamination levels in collected plant tissue and conduct investigations on the endemic reed which was present at site one of the tailings sites. Based on the earlier work by Harrison et al., 2019 and Broadhurst et al., 2019, the high yield of bamboo and the significant phytoremediation potential of kenaf and hemp, and the high multi-product potential of these fibre plants make them an attractive opportunity for regenerative agricultural systems, however larger scale pilots are needed to assess the plants' dynamics on different types of sites.

Figure 3.13 Potential pilot planting sites identified during initial site visit

Table 3.6 Summary of the opportunities and risks identified in the conceptual phase of the CoP project

Opportunities	Risks
Both bast fibre and bamboo have multi-product potential	Establishing end-markets for various products. Legal issues around crop types (invasive species, etc.)
Phytoremediation potential of fibre plants presents an opportunity to remediate and create integrated metal recovery flowsheet	High site contamination may limit product potential
Bamboo has a potential for wood products as a replacement for timber	Bamboo plants have higher water requirements. Competition with current timber industry may limit growth of local bamboo wood product industry.
Bamboo high volume and medium value products can create higher job potential	End-markets to sustain long term growth of industry
Bast fibre are the better downstream option to produce “green” textiles and high-end niche products	High skill level required and lower job creation potential

Table 3.7 Plant species planted on the sites in the preliminary campaign

Site number	Site name	Plant species planted	Comments
1	Post office	Kenaf (*Hibiscus cannabinus* L)	Very clayey categorised as “less contaminated” soil type.
2	Mponeng trench	*Bambusa balcooa, Dendrocalamus asper* and *Phyllostachys humilis*	Evidence of run-off water with a trench where flooding was expected during rainy season.
4	Cattle gate	Kenaf; *B. balcooa, D. asper* and *P. humilis*	Tailings spill a year ago with top 30 cm comprised of very fine tailings material.

13	Cricket field	Kenaf	“Uncontaminated soil”
15	Savuka TSF	*B. balcooa, D. asper* and *P. humilis*	Top of TSF with abundance of endemic reed species.

Other local economic development and land use initiatives

Local economic development (LED) and post-mining land use approaches across the various mine operations in the Far West Rand focus on agricultural initiatives, infrastructure development, job creation and enterprise development as part of integration into local IDPs (see Table 3.8). The LED projects form part of the SLPs, and there are increasing efforts to align them with post-mining land use development initiatives. Harmony’s LED at Kusasalethu is supporting the Wedela Agricultural Project, launched in 2019, various SMMEs and community enterprise development. They plan to use mine impacted land to develop an agribusiness sector, both for small-scale and commercial production, with a focus on planting vegetation to create carbon sinks and trees that have high-density wood (Harmony, 2020). Community development activities at Mponeng mine included revegetation and potential agricultural development (AngloGold Ashanti, 2016) but when Harmony acquired the mine from Anglo Gold Ashanti in October 2020, implementation of development projects (including COP) was delayed. Sibanye-Stillwater has various LED projects in place across their Driefontein, Kloof and Cooke operations, which span land-use, infrastructure, and enterprise development. To align LED with post-mining land use development, their key LED projects are focusing on the establishment of projects which will support the development of the Bokamoso Ba Rona project discussed in Case Study 2 (Sibanye-Stillwater, 2020).

In 2018 Sibanye-Stillwater traded selected assets from its West Rand Tailings Retreatment Project (WRTRP), subsequently renamed Far West Gold Recoveries (FWGR), for 38.05% shareholding in DRDGold, and in 2020, increased its holding to 50.1% securing majority shareholding. The land use identified specifically for the FWGR site includes rehabilitation with indigenous vegetation to support vegetation cover (Digby Wells, 2015). Gold Fields’ LED initiatives at South Deep span across projects relating to housing, health and infrastructure development, with key development projects such as Jachtfontein and Kalbasfontein agricultural support programmes and contribution towards the construction of health and education facilities (Gold Fields, 2018). South Deep’s most likely post-mining land use options identified include pasture for grazing, ecological conservation areas and a conservation and wildlife rehabilitation (Gold Fields, 2012). Blyvoor’s LED initiatives largely focus on services such as the refurbishment of the Ekuphakameni Wastewater Treatment Works and maintaining the waste management service in the Blyvoor Village. Post-mining land use of the Blyvoor site is currently expected to rehabilitate the land for grazing and wilderness areas (Golder, 2018; Blyvoor Gold, 2021). Despite the various LED projects being implemented as part of the SLPs at the various operations, there continues to be a lack of integration in development initiatives, rehabilitation and post-mining development, which continues to pose a risk to long-term regional development beyond mining activity.

<u>Energy supply</u>

Due to the high solar energy potential (Figure 3.14) in the West Rand, studies are underway to determine the feasibility of the development of renewable energy projects. The Gauteng Infrastructure Financing Agency (GIFA) has identified up to 11 sites in the West Rand area, which the Gauteng provincial government has made available through partnerships with local mining companies. Feasibility studies have confirmed the sites to have the appropriate topography and solar radiance levels that make them “highly suitable” for solar farm clusters (Slater, 2022). The GIFA has completed additional environmental assessments for nine of the identified sites and two additional sites will be provided by Sibanye-Stillwater (Slater, 2022). However, some of the land earmarked by GIFA for solar development is not mine-impacted and has the potential to be used for agriculture, which may need careful consideration to balance the land-energy usage in the long term (Slater, 2022). Sibanye-Stillwater is planning solar PV capacity of 50 MW in the West Wits area, with the plant expected to start operations in 2023 (more detail on the project is covered under case study 2). Gold Fields is also expected to commission a 40 MW solar plant by mid-2022 to produce power for the South Deep mine (Gold Fields, 2021). Due to the high solar potential in the West Rand potential linkages to the development of green hydrogen production along the proposed hydrogen corridor have been identified (West Rand District Municipality, 2021).

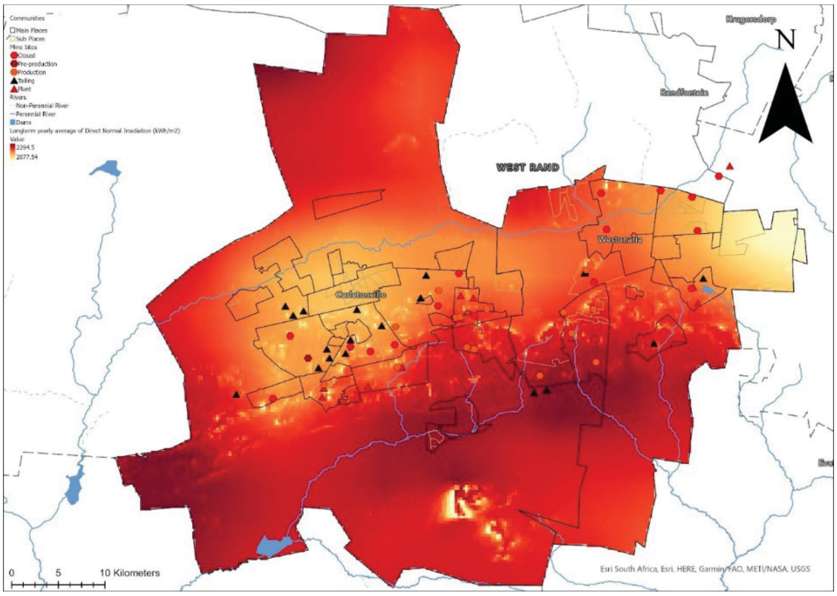


Figure 3.14 Solar irradiation in the West Wits

Table 3.8 Local Economic Development projects and post-mining land use initiatives in the Far West Rand

Company	Mine	Local Economic Development initiatives in SLPs			Proposed post-mining use	
		Land	SMME development	Infrastructure	Land	Infrastructure
Harmony	Kusasalethu	Wedela Agricultural Project – Vegetable Production (incl. Solar energy project to support Wedela)	Support to SMMEs **Planned over next 5 years	Small Business Centres – Fochville and other towns / townships	Agriculture and agri-processing Planting of vegetation to create carbon sink Trees with high-density wood.	Repurposing old mine-site buildings for alternative accommodation for host communities
Harmony	Mponeng			Indoor Sports Centre Wedela Community Care Centre Khutsong Community Health Care Clinic Kokosi	Plantation forest for revegetation on 14 km^2 farm to be built by next land buyer or investor	
Sibanye-Stillwater	Driefontein	Establishment of nursery (trees and seedlings for rehabilitation and agroforestry) Farmer Out-grower Scheme	Manufacturing Incubator (support SMMEs)	Blybank Multipurpose Hall (to support community gatherings, recreational, cultural and educational activities).	Farmers in Farmer Out-grower Scheme allocated land and linked to commercial farmers in Bokamoso ba Rona project	Buildings to be used by a third party
Sibanye-Stillwater	Kloof	Establishment of Farmer Out-Grower Scheme Support community Agricultural Cooperatives (vegetables and flowers)	Manufacturing Incubation hub (to Support SMME development)	Westcol TVET establishment Waste Management project to support waste disposal within municipality through equipment procurement (sorting machines, compressor machines, bins, recycling machines and cutters). Youth Centre establishment and Multi-Purpose Centre – Badirile refurbishment	Participating small farmers from Farmer Out-grower Scheme will be allocated land and linked to commercial farmers participating in the Bokamoso ba Rona project	
Sibanye-Stillwater	Cooke	Support community Agricultural Cooperatives (vegetables and flowers) – reallocated to Kloof Eradication of invasive alien species, Nursery project	SMME development – Protective clothing Manufacture	Thuto-Bokamoso Primary School infrastructure upgrade. 3. Formalisation of Bhongweni Settlement Project (housing and township development)	Progressively reinstate landscape: Pasture for grazing, support on-site and surrounding game- and stock farming and related activities.	
DRD Gold	FWGR	*LEDs Fall under Sibanye-Stillwater			Decontamination, rehabilitation with indigenous vegetation.	
Gold Fields	South Deep	Agricultural Support Programme (Jachtfontein & Kalbasfontein)	SMME funding & Business support centre (Westonaria)	Site and construction of clinic (Hillshaven) Business support Centre Partnership for Construction of West Rand Academy (TVET with Sibanye-Stillwater) Construction of Dual Purpose Library (Zuurbekom)	Options include pasture for grazing, ecological conservation areas and a conservation and wildlife rehabilitation.	

Blyvoor Gold	Blyvoor	Refurbishment and operation of the Ekuphakameni Wastewater Treatment Works. Clean storm water channels in Blyvoor Village Waste management service in Blyvoor Village	Grazing and wilderness land capability	

3.3 Case study 2: Bokamoso Ba Rona – West Rand goldfields

3.3.1 Context

Mining in the West Witwatersrand (the West Rand) goldfield began in the late 1880s during the gold rush to the Johannesburg area. The Randfontein Estates Gold Mining Company was established in 1889 and the town of Randfontein was established in 1890 to serve the new mine. It was administered by the town of Krugersdorp until it became a municipality in 1929. Mining expanded rapidly and by 1959 Randfontein had 28 shafts and over 21,000 employees and was the world's largest gold mine (SAIMM, 1989). In the 1960s mining in the area became dormant as the focus shifted to the Far West Rand, but exploration revealed new gold deposits to the south of Randfontein. Cooke Section (shaft 1 and 2) and a new plant were established in the 1970s to produce gold and uranium. By 1978, Randfontein employed 13,000 men who were housed in mine houses, hostels and flats (SAIMM, 1989). Cooke section expanded in the 1980s with two new shafts and a new plant. Sibanye-Stillwater acquired Cooke in 2013. Underground operations ceased at Cooke in 2017 and current production comes from surface operations which are treated at Cooke and Ezulwini plants. The life of mine is 2025 and currently employs 915 people (Sibanye-Stillwater, 2022).

Today, Randfontein has a diversified economy which includes engineering, food processing, and textile manufacture, and the West Rand area contributes close to 4% of the Gauteng Province GDP. Mining accounts for 30% of the West Rand District Municipality's GDP output (36% in Randfontein, 72% in Westonaria), whilst agriculture accounts for just under 2%. Mining employs about 45,000 people in the West Rand District Municipality while agriculture employs around 6,342 people. West Rand agriculture output equates to around R600 million per annum with nominal output showing a steady decline since 2016. In 1998, the West Rand District Municipality (DM) had four local municipalities – Merafong City LM, Westonaria LM, Randfontein LM and Mogale City LM (Figure 3.15). In 2016 Randfontein and Westonaria were combined to form Rand West City LM. Most of the land is privately owned; mining companies own 6% of land in Randfontein LM and 34% of land in Westonaria LM (Rand West City Local Municipality, 2015).

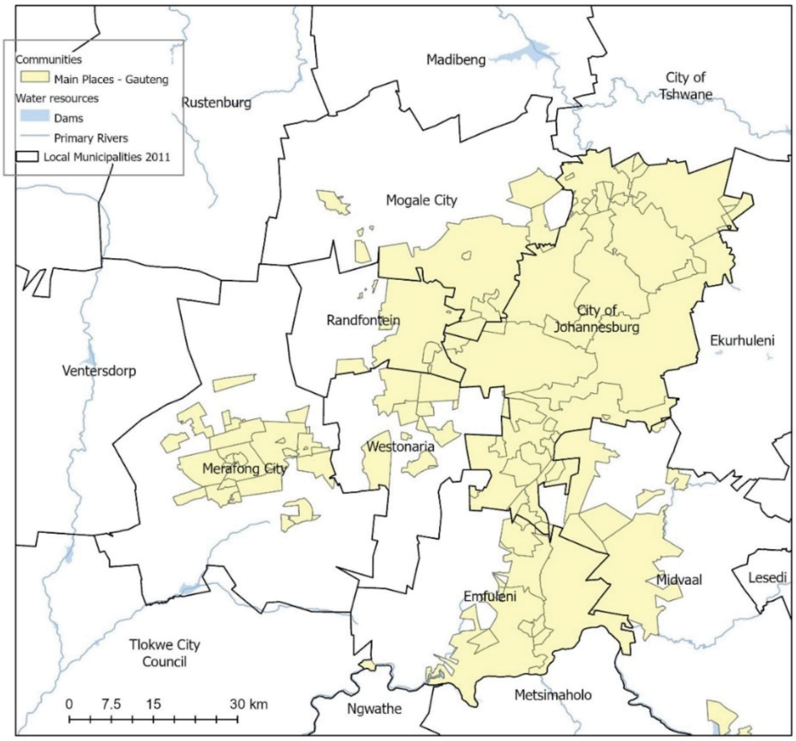


Figure 3.15 Map of local municipalities and main places in the West Rand area

3.3.2 Social vulnerability

The West Rand DM was home to 820,992 people in 2011, with 44% of those in Mogale City LM and 24% in Merafong City LM (see Table 3.9). The mining dominated LMs of Westonaria and Merafong City have higher percentages of men, and white people but lower education levels, employment levels and service delivery. Randfontein LM and Mogale City LM have very similar demographics, but Mogale City is better off in terms of education, employment and water access.

Table 3.9 Summary of West Rand District local municipalities in census 2011 (data source: StatsSA, 2012)

Local municipality	Population in 2011	Gender (% male)	Race (% non-white)	Formal dwellings (% persons)	Education (% completed Grade 12)	Employed (% of labour force)	Water access (% in dwelling or yard)
Mogale City	362,421	51.0	79.0	73.5	47.3	72.1	89.7
Randfontein	149,283	50.2	79.9	80.0	44.5	69.9	89.1
Westonaria	111,768	54.7	93.0	59.0	31.9	66.6	71.3
Merafong City	197,520	54.3	88.2	74.7	33.9	69.1	84.9
Total	820,992	52.2	83.3	70.1	41.6	70.2	85.5

3.3.3 Environmental impacts and risks

Land

Terrain influences climate and soil characteristics and plays a key role in land suitability. The topography of the West Rand District Municipality (WRDM) ranges from the steep slopes of the Magaliesberg in north to large areas with gentle slopes in the centre and south. The northern regions of the Rand West City LM (previously the Randfontein LM) are situated at higher altitudes and forms the watershed between the Vaal and the Crocodile Water Management Areas. The Gatsrand mountain range dissects the WRDM running east – west through the Marofeng City Local Municipality and the central regions of the Rand West City LM (formally the northern region of the Westonaria LM). The elevated ridges are ecologically sensitive due to their micro--climate conditions.

An area of concern to development are the dolomitic rock formations in Merafong and Rand West LMs (see Figure 3.16) which make the region prone to sinkholes, the majority of which are due to mine dewatering, ingress of water from leaking water-bearing infrastructure and poor storm-water management (Nealer, 2020). Sinkholes can damage water and sewerage infrastructure and in 2016 the formation of sinkholes in the Khutsong, Welverdiend and Carletonville areas become so severe that the local municipality declared a local state of disaster (ibid).

A key environmental feature of the WRDM are the wetland systems associated with the Wonderfonteinspruit, Leeuspruit, Loopspruit and other tributaries. The key wetlands include the Abe Bailey Nature Reserve, a protected area (Figure 3.18), the Loopspruit, the Wedela, and the Piet Viljoen Park wetlands (ICLEI, 2017). Wetlands in the district are under severe threat due to deliberate draining, development and expansion of urban and agricultural areas, and pollution (ibid). Damage to wetlands results in limited functionality and a decrease in the ability to provide valuable ecosystem services.

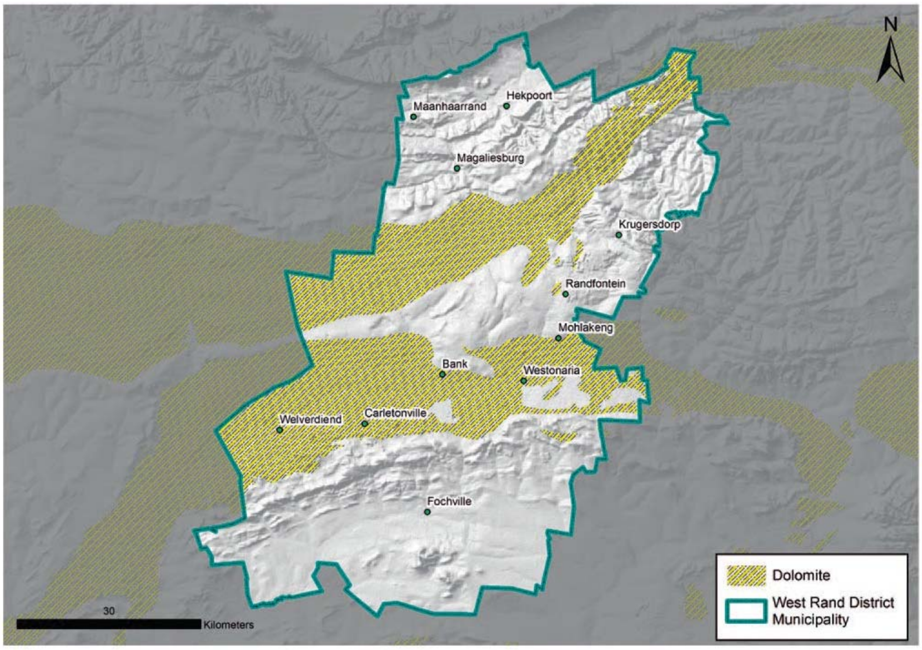


Figure 3.16 Location of dolomite rock formations in West Rand District Municipality (ICLEI, 2017)

Other protected areas occur in the Mogale City LM and include the Cradle of Human Kind world Heritage Site, the Krugersdorp and Blougat Municipal Nature Reserve, the Walter Sisulu National Botanical Garden, and the Magaliesberg Protected Natural Environment (see Figure 3.17a). The district has a significant area of high and moderate potential arable land (Figure 3.17b) which is currently used for agriculture but is also within mine boundaries.

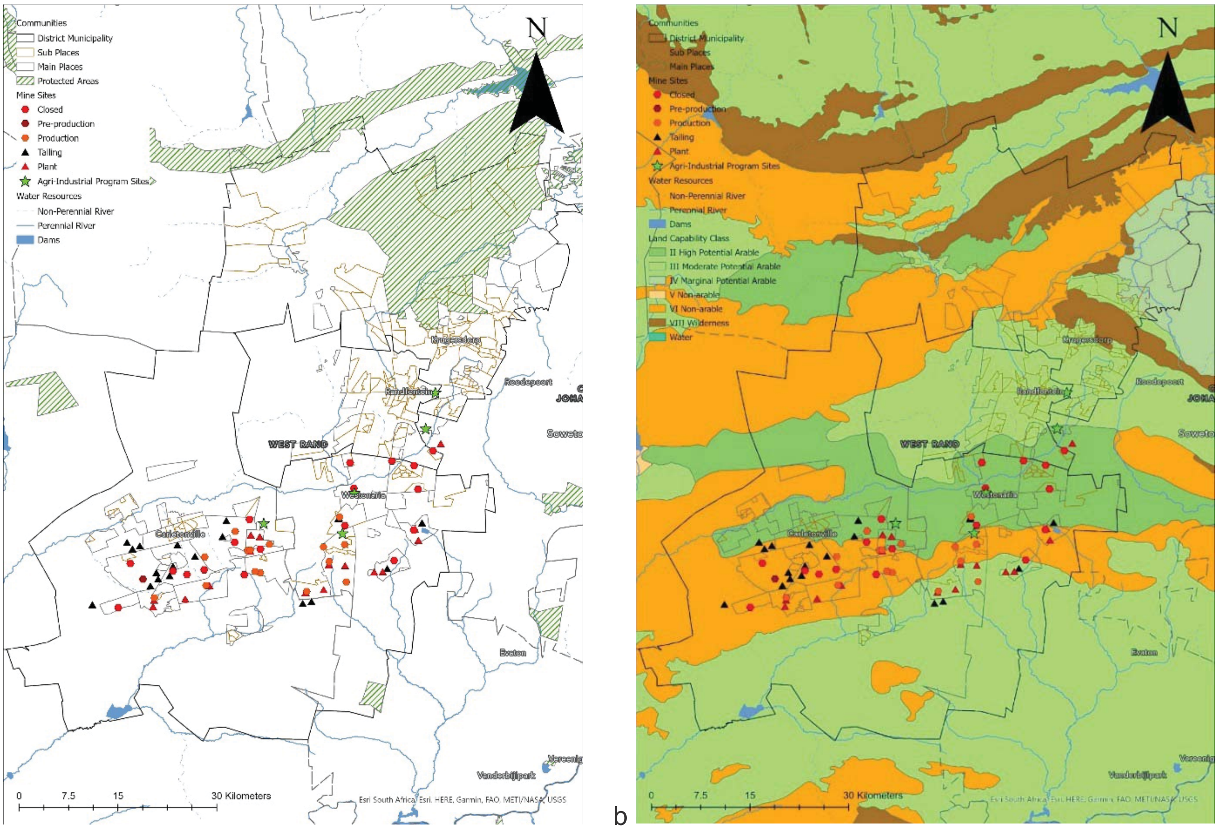


Figure 3.17 Maps of a) protected areas and b) land capability in the West Rand District Municipality

Water

Two Water Management Areas (WMAs) are located within and just outside West Rand DM, namely the Upper Vaal WMA and the Crocodile (West) Maric WMA, divided into north and south sections by a watershed. Several main river systems intersect West Rand DM, namely, inter alia the Skeerpoort River, Blaauwbankspruit, Magalies River, Rietspruit, Crocodile River, Wonderfonteinspruit, Loopspruit and Leeuspruit. Freshwater is the district’s most limiting natural resource. The main threats to both of West Rand DM’s WMAs water availability are climate change and agricultural and mining activities. Domestic water in residential areas is provided by Rand Water, which generally abstracts water from outside West Rand DM.

Water quality is of significant concern in the West Rand with all rivers classified as critically endangered or endangered (BKS, 2013). Whilst sewerage spillages are of concern, the two largest contributors to pollution are mining and agricultural activities, mainly salinisation, nutrients (particularly nitrogen and phosphate), acid mine drainage and radioactive elements (ibid). Of particular concern is the pollution of the Wonderfonteinspruit river by mining activities which flows from the Krugersdorp are to Donaldson Dam near Westonaria where it is channelled into a large pipeline, which carries the water over the dolomitic groundwater compartments until it discharges near Carletonville. This diversion of the river from its natural channel has been done to allow deep gold mining to proceed below the outcropping dolomite. There it forms the large wetland area known as Abe Bailey Wetlands before eventually converging with the Mooi River which feeds into the Boskop Dam. Coetzee et al. (2004) found that fluvial sediments found in dams, wetlands and the streambed of the Wonderfonteinspruit frequently contain significantly elevated uranium concentrations, sometimes even exceeding those in tailings deposits and other primary sources of uranium pollution. The mean values were also found to significantly exceed not only natural background concentrations, but also levels of regulatory concern for cobalt, zinc, arsenic and cadmium. The presence of uranium and other metals in the river sediment and water poses a risk to eco-systems, livestock as well as local communities who make use of the surface and ground waters for domestic, agricultural, fishing and recreational purposes (BKS, 2013).

Biodiversity

According to the Gauteng Protected Areas Expansion Strategy (GPAES), Critical Biodiversity Areas cover 27.5% of the district and Ecological Support Areas cover a further 19% of the district (Figure 3.18) while protected areas cover just over 2% of the municipality (Figure 3.17). There are at least 12 threatened plant species and 20 threatened animal species within WRDM as well as eight nationally listed threatened ecosystems. Several veld types occurring in the district are considered to be threatened, including the Soweto Highveld grassland, Rand Highveld Grassland and the Egoli Granite grassland (BKS, 2013). Merafong City LM has four areas of interest in the GPAES, namely Wonderspruit eco-corridor deemed important for migration and repopulation of plants and animals in a changing climate, Gatsrand eco-corridor, Loopspruit ecocorridor and the Losberg Critical Biodiversity Area (Merafong City Local Municipality, 2020).

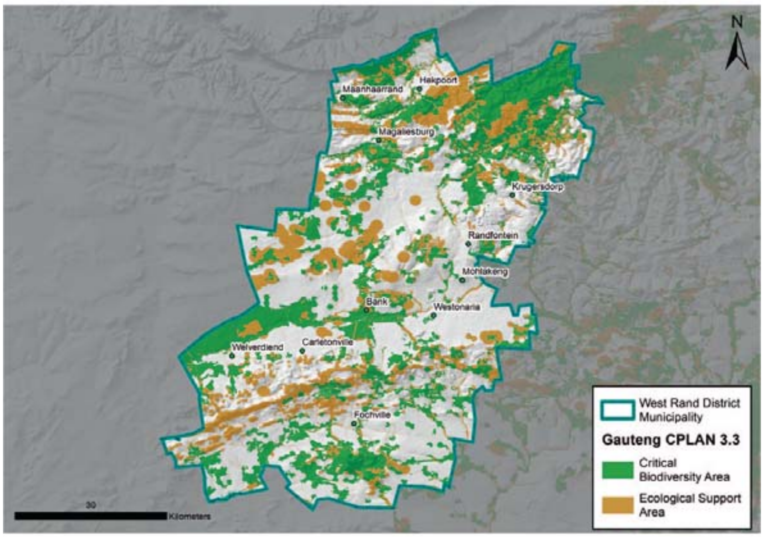


Figure 3.18 Critical Biodiversity Areas and Ecological Support Areas in West Rand District Municipality (ICLEI, 2017)

Air pollution

There is little to no air quality monitoring within the WRDM. Although the Mogale City LM has an air quality monitoring station, the SAAQIS shows that no data was captured by this station in the period 2020-2021. To fill data gaps, AirVisual provides some *estimated* Air Quality Index (AQI) data based on satellite PM2.5 data for locations which are lacking ground-based measurements. This data show that estimated PM2.5 levels in Randfontein, Carletonville, Westonaria and Krugersdorp are generally several orders of magnitude above World Health Organisation (WHO) standards.

Several research studies (e.g. Mpanza et al., 2020; Nkosi et al., 2021) have found that PM10 levels frequently exceed the national air quality standard (180 µg/m^3 for 24-hour period) recommended national exposure limits in areas closer than 1 km from mine residue deposits in the WRDM. It should be noted that these levels are significantly higher than the WHO standard (50 µg/m^3 for a 24-hour period), with new and more stringent national standards expected in 2030.

Mining companies are required by law to monitor dust fallout from their operations. Whilst the Merafong City LM state that dust fallout is slight to moderate and falls below the residential threshold, this data are, however, not generally available publicly.

Waste

The entire WRDM is characterised by significant quantities of mine residue deposits, including tailings storage facilities (TSFs) or tailings dams, waste rock dumps, open-cast excavations and quarries, water storage facilities, tailings spillage sites, footprints left after the re-mining of TSFs, and a mixture of other waste on former mine properties (GDARD, 2012). TSFs make up the majority of mining residues and whilst some are still active, many are defunct and abandoned. Massive quantities of mine waste are being reprocessed for their gold content, with the reprocessed tailings deposited in new mega-dumps or onto existing TSFs (Bobbins and Trangoš). In accordance with the Environmental Management Framework published in 2013 (BKS, 2013), there are currently approximately 52 active and inactive TSFs in the WRDM. Fourteen tailings dams were identified in Mogale City LM, 13 in Rand West LM, and 23 in Merafong City LM (Figure 3.19).

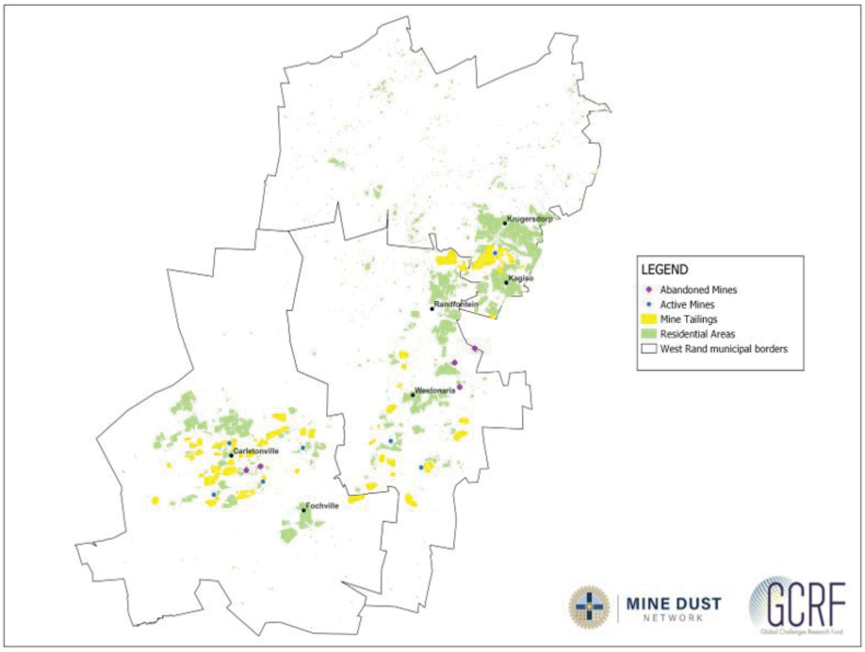


Figure 3.19 The location of tailings storage facilities and communities in the West Rand

These tailings are responsible for much of the air, water and soil pollution within the District (Bobbins and Trangoš, 2018, GDARD, 2012). This is largely due to mining waste containing metals, including uranium and pyrite that were not removed from mined ore before being deposited in slimes dams or TSFs. As a result, mining waste is often highly toxic and, if not maintained correctly, can pollute the surrounding environment through dust dispersion and seepage or run-off of water, which is frequently highly acidic and enriched with dissolved salts and elevated metals. The ongoing urbanisation of the Witwatersrand has seen the gradual encroachment and expansion of human settlements near mines and tailings dumps, where communities encounter pollutants from the mines through inhalation, ingestion or skin contact. In 2003 GDARD developed a set of buffer zones to demarcate safe distances for development around mine residue areas in places where developments may result in harmful effects on human health and wellbeing. Buffers were established to support decisions around the provision of housing, though cannot be enforced under South African law as they are guidelines (GDARD, 2009). Two buffers were devised, a best-case scenario which denotes land within a 1 000 m zone around mining waste, and a worst-case scenario which denotes land within a 500 m zone around mining waste (GDARD, 2003; GDARD, 2009). Dust levels are generally acceptable 500 m away from mining waste, provided there are adequate mining waste practices in place. Beyond a distance of 1 000 m, dust from mining areas cannot be detected (ibid). However, there is little quantitative data to support the establishment of “safe” buffer zones, with several external factors influencing the levels and effects of exposure. For instance, Nkosi et al. (2021) indicated high prevalence of high blood pressure in the exposed communities, and elderly people living within 1-2 km of mine dumps were at an increased risk. In contrast Iyaloo et al. (2020), only found adverse respiratory health effects occurring at distances of < 500 m. Furthermore, in many cases these buffer zones are not adhered to with informal communities frequently living and working only tens of metres away from slimes dams, rock dumps and AMD-polluted water (Bobbins and Trangoš, 2018).

3.3.4 Land use opportunities

Bokamoso Ba Rona Project

The Bokamoso Ba Rona project is an initiative in the West Rand focusing on agri-industrial development to support communities in the region beyond mining (Sibanye-Stillwater, 2018). The project was launched in 2018 through a multi-stakeholder collaboration between Sibanye-Stillwater, the West Rand Development Agency

(WRDA) representing the interests of the West Rand District Municipality, Merafong Local Municipality and Rand West Local Municipality, the Far West Rand Dolomitic Water Association (FWRDWA), the Public Investment Corporation and the Gauteng Infrastructure Financing Agency (West Rand Development Agency et al., 2018). The project was formed as a combination of existing initiatives in the West Rand to support the development of agri-industrial hubs and economic diversification in the area (ibid). The initiatives, namely the (1) Sibanye-Stillwater Agri-initiative, (2) Merafong BioEnergy Industrial Park and (3) Agri-Parks Programme, were all exploring the feasibility of establishing agricultural projects and downstream value-chains. The aims of the three projects were as follows:

1) Sibanye-Stillwater West Rand Agri-Initiative sought to develop 15,000 ha of land in the West Rand (see Figures 3.20-22) to establish an alternative post-mining economy, to create sustainable community developments as part of the WRDM's development strategy.
2) Merafong BioEnergy Industrial Park sought to establish a bioenergy eco-industrial park that could take advantage of opportunities around agriculture and economic clustering. The emphasis is on opportunities to utilise unused mine-impacted land and uncontaminated land owned by mines for the production of energy and commercial agricultural crops. The project also looked at the aggregation of regional feedstocks, including organic waste, agricultural residue, agro-processing waste and other waste streams into agricultural value chains. Following the feasibility in 2017, the development of a BioEnergy Park and Solar farm were identified as potential projects.
3) Agri-parks programme initiated by the Department of Rural Development and Land Reform (DRDLR) sought to support agro-production, processing, logistics and services in Randfontein. The DRDLR purchased farmland in the WRDM and operated Bambanani Farm, producing fruit for export.

In 2018 stakeholders across these key initiatives recognised the alignment in objectives and the potential to collaborate. Subsequently stakeholders elected to combine efforts into the Bokamoso Ba Rona project, with the specific overall aim to create a large-scale agriculture and agro-processing industrial hub in the West Rand. The Bokamoso Barona project aims at creating a sustainable post-mining economy through:

- creating employment with a particular focus on agriculture, the development and transfer of skills and an emphasis on the creation of labour-intensive opportunities
- accelerating transformation by creating opportunities and providing ongoing development and training for the surrounding local communities and
- facilitating comprehensive and sustainable local socio-economic development.

The various partners are expected to contribute to the project through land, combining resources from the initial separate initiatives, facilitating stakeholder engagement and securing funding (Table 3.10).

Table 3.10 Stakeholder contribution and commitment for Bokamoso Ba Rona (WRDA, 2018)

Stakeholder	Contribution to Bokamoso Ba Rona project
Sibanye-Stillwater	Land earmarked initially for the West Rand Agri-Initiative and community development projects to the project and the Merafong BioEnergy Industrial Park project.
Far West Rand Dolomitic Water Association	Will contribute land to the project which was identified for the Merafong Agri-Industrial Park and community developments projects.
West Rand Development Agency	Structure arrangements with the relevant municipal structures and provide assistance with engagement with the surrounding communities.
Gauteng Infrastructure Financing Agency	Provide expertise, networks and support stakeholder engagement to achieve the project's objectives.

Public Investment Corporation	To assists securing project development funding and initial start-up capital and long-term funding required for implementation and sustainability of the project.

Figure 3.20 Land made available to the Bokamosa Ba Rona project by Sibanye-Stillwater in the Randfontein area (Sibanye-Stillwater, 2018)

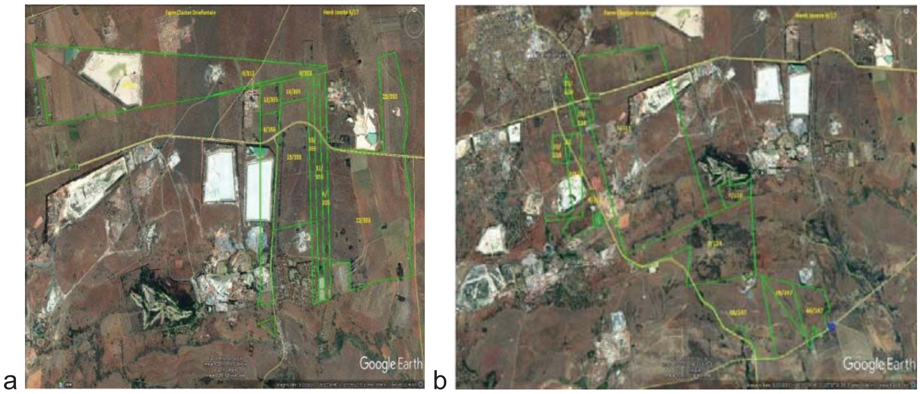


Figure 3.21 Land made available to the Bokamosa Ba Rona project by Sibanye-Stillwater in the Driefontein area (Sibanye-Stillwater, 2018)

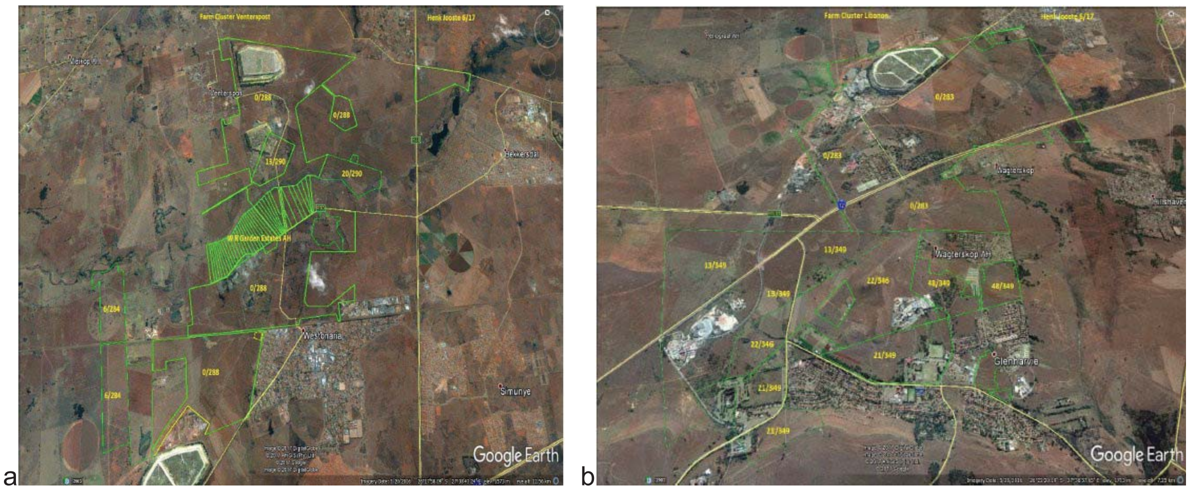


Figure 3.22 Land made available to the Bokamosa Ba Rona project by Sibanye-Stillwater in the Westonaria area (Sibanye-Stillwater, 2018)

Project development

The Bokamoso Ba Rona project will be ongoing for 15 to 20 years and plans to focus on long-term job creation and enterprise development in surrounding communities. A development agreement concluded in 2019 with the programme management consortium comprising Talmar Impact Investments, Zutari and Cliffe Dekker Hofmeyr will frame the scope of work to develop the programme design for commercial sustainability and optimised delivery of socio-economic benefits (Sibanye-Stillwater, 2019b). It has three phases (Figure 3.23) and is following a multi-dimensional approach to unlock pre-development funding, grant funding and financing for identified short-term pilots and/or projects for Phase 1 and part of Phase 2 and long-term financing for implementation at scale (Phase 3). Funding options include multi-national grant funding agencies (e.g. World Bank and the African Development Bank, AfDB) and regional development agencies such as the Development Bank of Southern Africa (DBSA). As part of Phase 1 seed funding the AfDB provided grant funding for preparation of projects under the continental Staple Crop Processing Zone programme; this work will see the conclusion of developer and funder contracts to support the growth of local agriculture in the West Rand. Funds have also been secured from local banks and Sibanye-Stillwater has earmarked SLP funding towards the project initiatives that support the development of local agriculture (Sibanye-Stillwater, 2022).

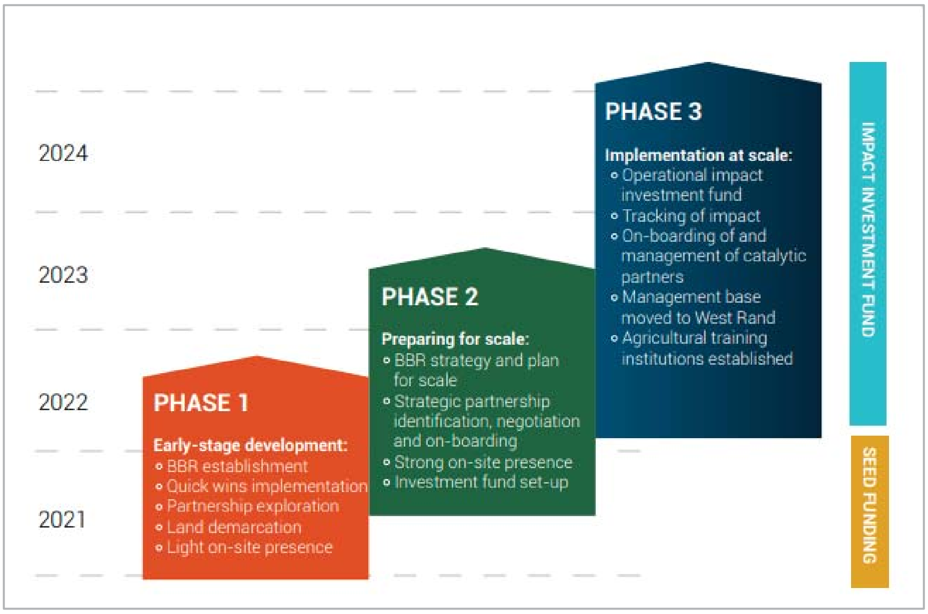


Figure 3.23 Bokamoso Ba Rona project development timeline (FWRDWA, 2022)

Land selection

As part of Phase 1 of the project's development Sibanye-Stillwater has earmarked land towards the development of the hub around its gold mining operations in Carletonville and Randfontein (see Figures 3.21-23). Sibanye-Stillwater and the FWRDWA have together made available ~ 30,000 ha of land in the Merafong City LM and Rand West LM (collectively the "project area") to facilitate the development of the project and an agri-industrial hub in the WRDM. Approximately 16,000 ha of the allocated land has historically been under agricultural production and some areas are still under production. The project area is characterised by generally flat terrain with some ridges in the southern areas. Areas with high potential for agricultural production are generally well buffered from mining activity and human settlement and have good production characteristics with a history of production of maize, sunflower, wheat, fresh produce and peaches.

Soil forms are predominantly Hutton and Clovelly soil forms in the northern half of the project area, and Glenrosa and Mispah soil forms (shallow, rocky/stony soils) to the south of the project area. These red, well-drained and aerated soils are generally well suited for agricultural production. The soils are generally deep with an apedal structure, implicating a sandy soil with little structure. Rehabilitated mine land will be incorporated for agricultural use over time as part of second order potential land as indicated on Figure 3.24 (FWRDWA, 2022). The project is assessing water quality and the viability of the treatment of acid mine water into potable water and water for agricultural use. The soils on the higher potential land are generally well suited to produce a wide variety of crops. However, it is important that the correct varieties are planted to minimize climatic risks. Most of the identified crops (Table 3.11) can be produced with different irrigation methods. Other potential crops such as herbs, medicinal plants and cherries will also be considered.

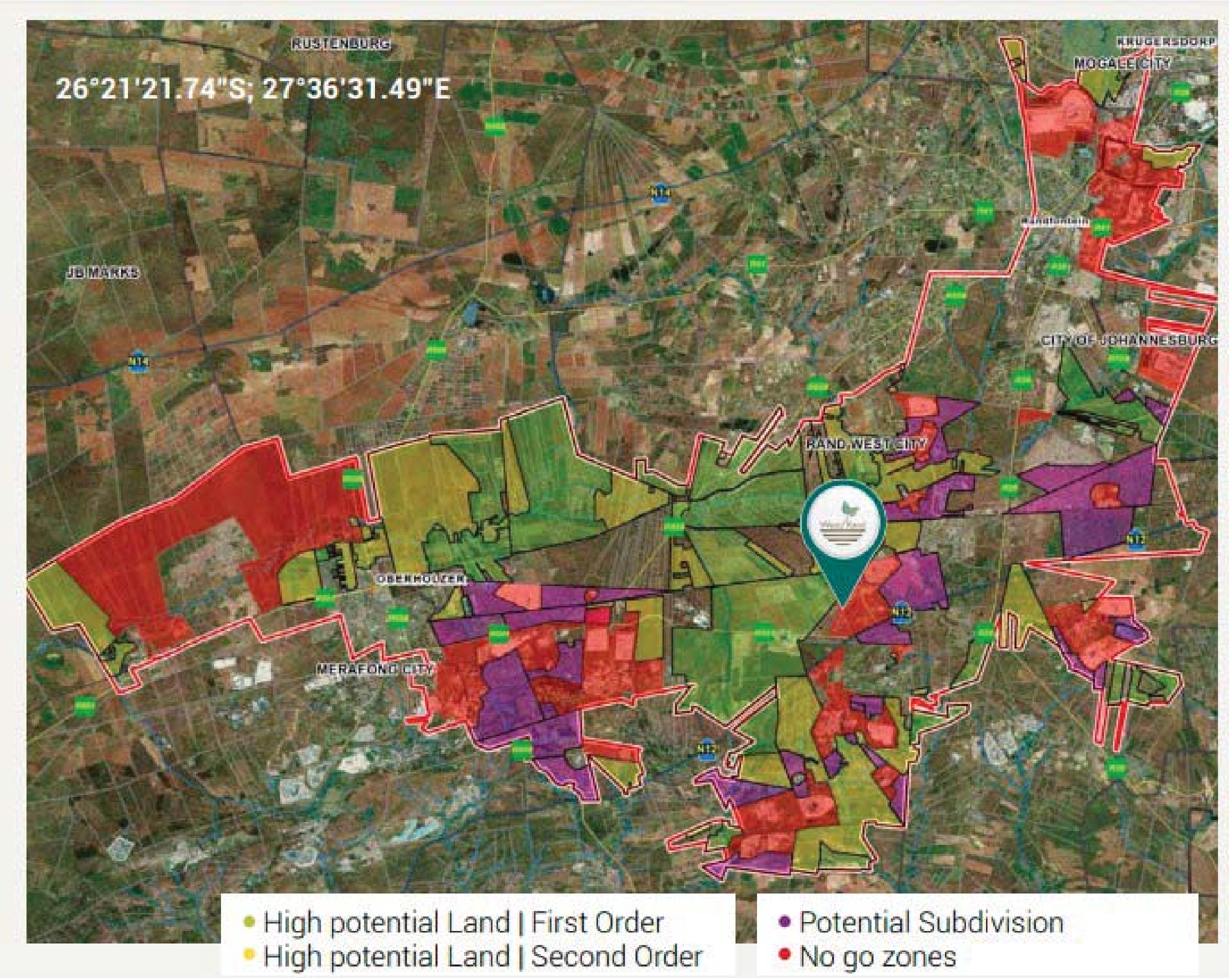


Figure 3.24 Bokamoso Ba Rona project land classification boundaries (FWRDWA, 2022)

Table 3.11 Range of crops initially identified for high potential land areas for the Bokamoso Ba Rona (FWRDWA, 2022)

Perennial crops	Annual crops (field)	Annual crops (vegetables)
Pecan nuts, Low-chill Apples	Groundnuts, Potatoes	Beetroot, Brinjals, Butternuts, Cabbage
Stone fruit: Apricots, Plums, Peaches, Nectarines	Soya beans, Sunflowers	Green beans, Lettuce, Onions, Sweet Potato
Blueberries	Sorghum, Wheat	Carrots, Sweet Pepper, Swiss Chard, Tomatoes

The project aims to focus on a regenerative agricultural system which will integrate livestock and plants in a single ecosystem (Figure 3.25). Crops will be rotated to maintain balance and keep the soil covered with other crops after harvest which can be grazed by livestock or harvested. A livestock management system is being designed to harmoniously integrate current livestock arrangements in the area with crop-based farming based on holistic management and structured grazing methods (FWRDWA, 2022).

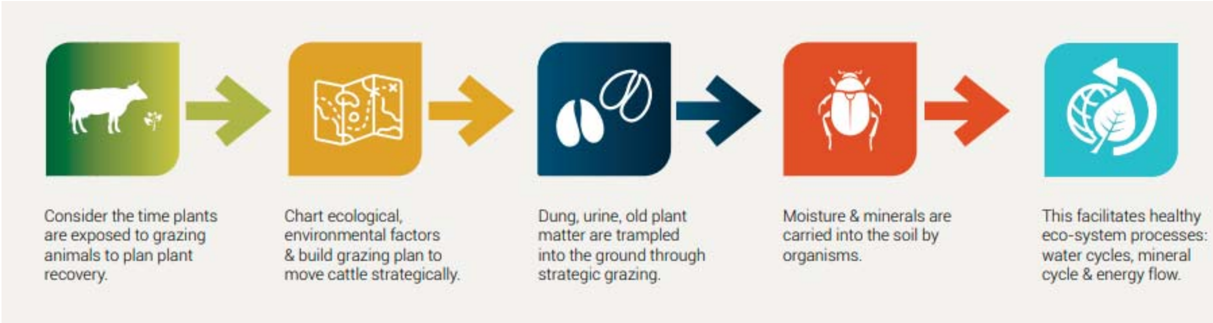


Figure 3.25 Bokamoso Ba Rona project regenerative agriculture plan (FWRDWA, 2022)

As part of the long-term sustainability of the development, an agri-industrial hub will be developed to transform the agricultural outputs into various downstream products in order to reduce agri-waste, extend the life of outputs and appeal to broad local and export markets (FWRDWA, 2022). The basic concept for the Bokamoso Ba Rona agro-processing flowsheet is shown in Figure 3.26. As part of the project's development, it will enlist multiple large-scale catalytic commercial operations to provide the foundation to support SMMEs and pilot different regenerative agricultural projects as part of the Farmer outgrower scheme described in the following section.

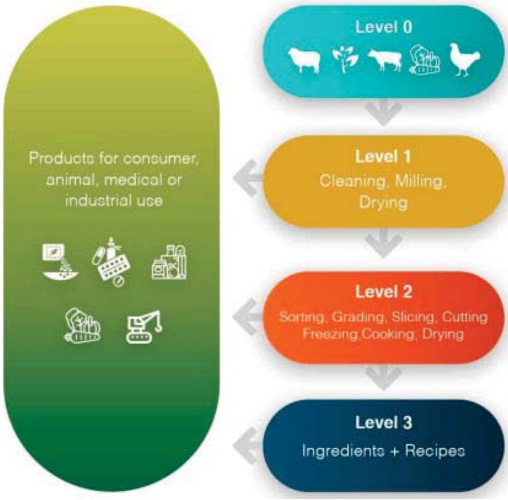


Figure 3.26 Bokamoso Ba Rona project agro-processing basic flow sheet process (FWRDWA, 2022)

<u>Farmer-out grower schemes</u>

To align local economic development with post-mining land use development, key Sibanye-Stillwater LED projects are focusing on the establishment of agricultural initiatives which will feed into the Bokamoso Ba Rona project. The projects include the Merafong nursery (to support trees and seedlings growth to be used for rehabilitation and agroforestry), farmer out-grower schemes and supporting community agriculture cooperatives (Sibanye-Stillwater, 2020; 2022). The Merafong nursery is being developed as part of Driefontein's LED projects and will propagate trees and other seedlings to support food security in communities situated in Merafong City Local Municipality (Sibanye-Stillwater, 2020; 2022). In Driefontein's farmer out-grower scheme, four farmer production units are being established on 20 ha of land (ibid). Participating small farmers will be allocated land and linked to the commercial farmers who are part of the larger agriculture development project. Similarly, Kloof mine's farmer out-grower scheme will establish four agricultural units on

20 ha targeting communities situated in Rand West City as part of the Bokamoso Ba Rona's project development (Sibanye-Stillwater, 2022). The development of community agriculture cooperatives is also being supported as part of growing local agricultural capacity. The You Reap What You Sow community cooperative project in Randfontein (Figure 3.31) has been established and is now operational with produce being sold in the community and other local businesses (ibid).

Figure 3.27 The You Reap What You Sow Co-operative in Mohlakeng (Sibanye-Stillwater, 2019)

<u>Livestock farming</u>

The Bokamoso Ba Rona project is currently assessing options around developing a large-scale regenerative livestock system to assist livestock owners in unlocking the commercial potential, while regenerating degraded grasslands and soil and sequestering carbon (FWRDWA, 2022). There is currently an informal arrangement between Sibanye-Stillwater and private livestock owners for grazing livestock on Sibanye and FWRDA owned land. An estimated 10,000 to 15,000 head of cattle, sheep and goats are grazing on 30,000 ha of land. Options to formalise the venture are currently under consideration as part of the development of a regenerative agricultural system. The project aims to design a holistic management system to consolidate and co-design a business model with livestock owners to couple traditional value system with modern economic value. The system will focus on maximising regeneration, designing, and establishing strategic processing facilities, as well as establishing formal offtake channels for livestock units and value-added meat products (FWRDWA, 2022).

Other land use opportunities

The West Rand has very high solar PV potential (Figure 3.28) and Sibanye-Stillwater is in the process of developing a 150 MW solar PV plant between the Driefontein and Kloof mining complexes to support its gold operations (Sibanye-Stillwater, 2020). Construction of the plant is expected to start in 2022, and the first 50 MW plant is to be operational in 2023 (Sibanye-Stillwater, 2021a, 2021b, 2022). Due to the location of the solar project, there is opportunity to form linkages with the Bokamoso Ba Rona project and offer post-closure electricity supply to communities (Sibanye-Stillwater, 2022). The solar plant is one of 11 'gamechanger' projects planned in the West Rand District, which are expected to have a significant impact on the region (West Rand District Municipality, 2021).

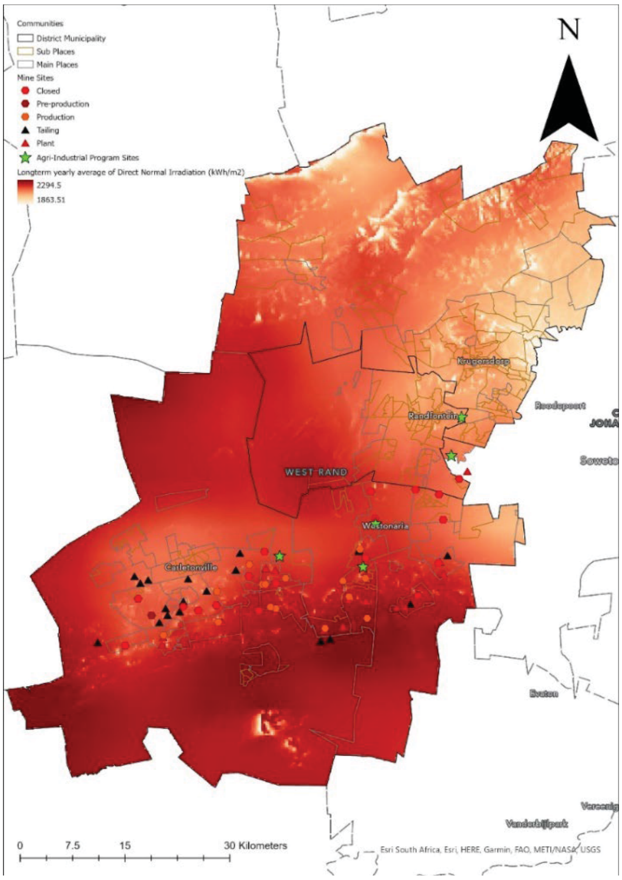


Figure 3.28 Solar PV potential in the West Rand area

Table 3.12 Summary of land use opportunities in the West Rand

Land use category	Description
Agriculture	Fibre crops, Livestock Farming, biomass crops, traditional crops, greenhouses, nursery
Industrial	Fibre processing, Agro-processing, Bio-refinery
Renewable energy	Solar PV plants
Community & culture facilities	Heritage sites, Historic sites
Conservation	Nature reserves, Protected sites

3.4 Case study 3: The Green Engine – Witbank coalfield

3.4.1 Context

The town of Witbank, now the city of Emalahleni, was established in 1903 to support the growing demand for coal being mined in the area since the 1870s. The Witbank landscape consists mainly of underground and open-cast coal mines and has the largest concentration of power stations in the country with Kendal, Matla, Duvha, Ga-Nala (Kriel) and Kusile. The Witbank coalfield extends some 90 km from the towns of Springs in the west to Belfast in the east, and 50 km from the town of Middelburg in the north to Rietspruit in the south, including the towns of Delmas, Kendal and Ogies. The Witbank coalfield supplies more than half of South Africa's saleable coal, reducing metallurgical coal and thermal coal for export and domestic markets (Hancox and Götz, 2014). Since the change in mineral legislation in 2004, the coalfield has seen renewed exploration and exploitation by several new junior and mid-tier miners, largely focused on the western sector of the coalfield around Springs and Delmas. Emalahleni is situated within the Emalahleni Local Municipality (LM) which is part of the Nkangala District Municipality of Mpumalanga Province. The Victor Khanye LM to the west and the Steve Tshwete LM to the west also host numerous coal mines. The area is characterised by conflicting land use demand between mining, electricity generation and agriculture. A strategic objective of Emalahleni LM's IDP is to prevent mining activity from encroaching onto high potential agricultural land and areas of high biodiversity; to ensure that the areas of mining activity are properly rehabilitated and that the agricultural value of the land be restored once the mineral resources are depleted (Emalahleni Local Municipality, 2021).

The Khwezela Colliery is an open cast thermal coal mining operation located near Emalahleni (see Figure 3.28) that produces coal for both the export and domestic markets (Thungela, 2022). Originally in the 1940-1980s the area was mined by underground methods on multiple seams at multiple collieries. Khwezela Colliery was formed by Anglo Coal in 2016 through a merger of their mining operations at Kleinkopje colliery – now Khwezela South – and Landau colliery – now Khwezela North – to reduce costs and remain financially viable. Khwezela North is bordered by Thungela's Klipspruit Colliery in the southwest, South Witbank Colliery in the northeast and Seriti's MMS Colliery in the east. Khwezela South is bordered by Glencore's Tweefontein Complex in the south and Thungela's Greenside Colliery to the west.

In 2021 Khwezela was sold to Thungela Resources Ltd as part of Anglo American's transition away from thermal coal (Thungela, 2022). Khwezela has a current life of mine of three years from Navigation pit but mineral resources at Bokgoni Pit (currently on care and maintenance due to economic and market conditions), the North West Block, Landau 1 and 2 and the Clydesdale Pan area at the adjacent Greenside Colliery, offer the potential for another 30 years (Thungela, 2022). The Kromdraai pit and the three adjacent mini pits – Schoongezicht, Umlalazi and Excelsior – in Khwezela North have been mined out and no coal resources remain (SRK, 2021).

There are several other coal mines and processing plants operating in the area shown in Table 3.13 and Figure 3.29. There are also many defunct mines – Castle Colliery, Clydesdale, Coniston, Highveld Colliery, Klipfontein, Phoenix, Rietspruit, Springbok, South Witbank, Tavistock, Transvaal and Delagoa Bay Colliery and Wildebeestfontein Colliery (Coaltech, 2004).

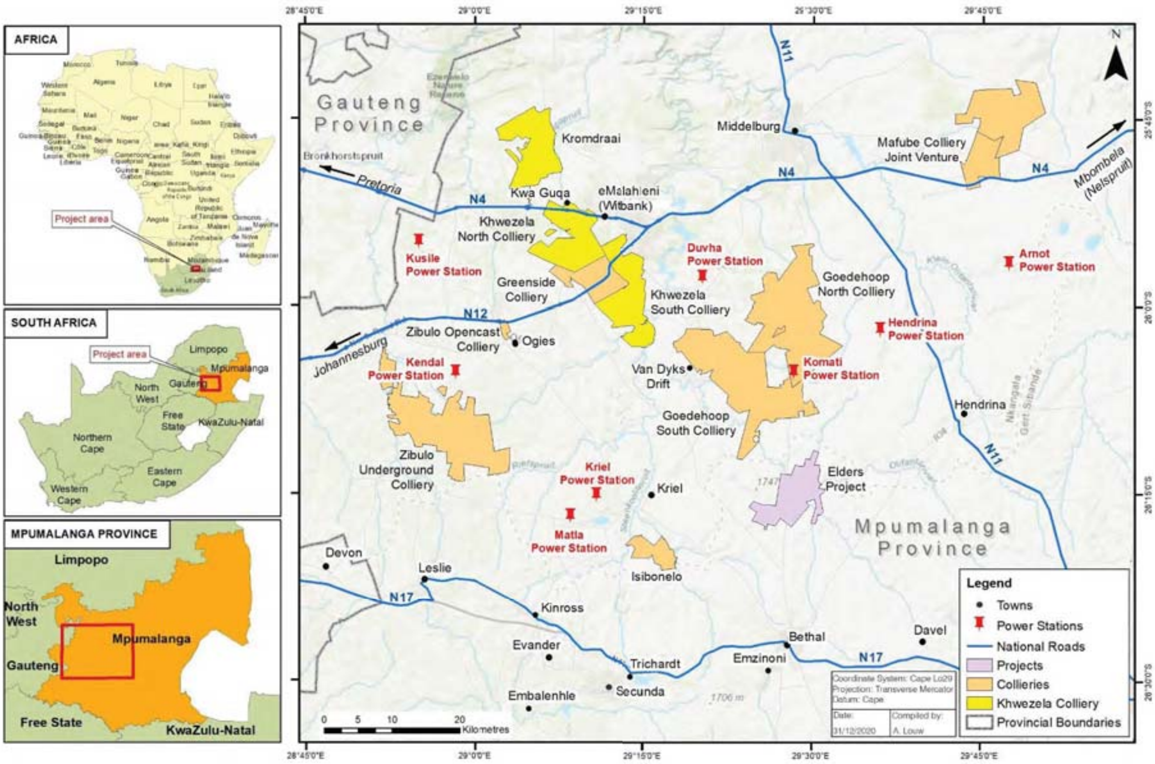


Figure 3.29 Khwezela Colliery location maps, highlighting Thungela's collieries (SRK, 2021)

Table 3.13 Collieries in the Emalahleni area (Anglo American, 2019; Exxaro, 2022; Seriti, 2022; Thungela, 2022)

Colliery	Type of coal	Mining methods	Ownership	Employees	Established
Khwezela North	thermal	Open cast	Thungela	4,752	1990
Zibulo	metallurgical	Underground, open cast	Thungela, South32		
Greenside	thermal	Underground	Thungela		
Goedehoop North	thermal	Underground	Thungela, Exxaro		
Isibonelo	thermal	Open cast	Thungela		
Matla	thermal	underground	Exxaro	2,501	1983
MMS	thermal	Open cast	Seriti	3,578	1979
Khutala	thermal	Underground, opencast	Seriti	3,239	1986
Kriel	thermal	Underground, opencast	Seriti	2,652	1975
Ntshovelo	thermal	opencast	Mbuyelo Coal		2010
Manungu	thermal	opencast	Mbuyelo Coal		2015
Goedgevonden	thermal	opencast	ARM & Glencore		
Tweefontein	thermal		Glencore		

3.4.2 Social vulnerability

The population of Emalahleni LM increased from 395,466 in 2011 to 455,228 in 2016, a growth rate of 3.2%, giving an estimated population of 500,343 in 2019 (Emalahleni Local Municipality, 2021). The population is expected to increase to 646,708 in 2030, which will require an additional 40,721 residential units, and the urban footprint will expand by an 3,721 ha (Emalahleni Local Municipality, 2021). The MSDF poses that the housing of mining and power station personnel be consolidated in existing nearby towns with a diversified economic base, e.g. Phola, Wilge, and Emalahleni (Emalahleni Local Municipality, 2021). In 2018, 30% of the population lived below the lower-bound poverty line of R575 per person per month. The unemployment rate of Emalahleni LM was 31% in 2011, and the number people dependent on social grants has steadily increased to 100,276 in 2021, roughly one fifth of the population (SASSA, 2021). At least 20,000 people received a Covid-19 special grant in 2020/21. Emalahleni LM has a huge housing backlog (estimated at 51,242 families) because of continuous influx of job seekers into the area. Currently 28,370 families live in 71 informal settlements and 20,196 families live in backyard dwellings[2]. Emalahleni LM contributes 30% to GDP of Mpumalanga, however, the projected annual GDP of Emalahleni is less than 0.9% between 2018-2023. Mining contributed almost 55% to the Emalahleni LM economy in 2017 and 19% to employment in 2013 (Emalahleni Local Municipality, 2021).

In this case study, the focus is on communities around Khwezela Colliery and thus in and around eMalahleni city, shown in Figure 3.30. Table 3.14 provides demographic information while Table 3.15 and Figure 3.31 measure a set of SDG socio-economic indicators for the diverse communities in this area. It shows that racial segregation is still in place, with white people living in the city, towns and on agricultural holdings, while black people mostly live in townships with much lower levels of basis services and living standards. Unemployment is worst in the townships at 38.4% though it is also high in the small towns.

Table 3.14 Communities in the Emalahleni case study area in 2011

Name	Type of community	Population	% Total population	Race (% non-white)	Formal housing (% persons)	Employed (% labour force)
Emalahleni	City centre and suburbs	88,479	29.5	45.1	89.5	86.7
Blesboklaagte	Informal settlement	1,437	0.5	100.0	17.6	55.7
Pine Ridge	township	2,110	62.5	99.6	98.7	75.9
Vosman		18,963		99.9	76.4	60.5
KwaGuqa		130,920		99.9	75.8	63.1
Hlanalikahle		35,108		100.0	79.7	56.5
Klarinet	town	9,822	5.5	99.9	91.2	62.0
Paxton		2,078		86.5	97.2	91.7
Clewer		4,569		91.5	93.2	72.1
Jackaroo AH	agricultural holdings	1,722	2.0	26.5	96.0	86.1
Dixon AH		4,354		90.5	99.5	85.9
Emalahleni NU*	farms	12,837		82.1	72.7	71.1
Total (ex NU)		299,562				

*this includes all non-urban (NU) land in the local municipality, not just the study area

[2] https://www.Emalahleni.gov.za/v2/human-settlement

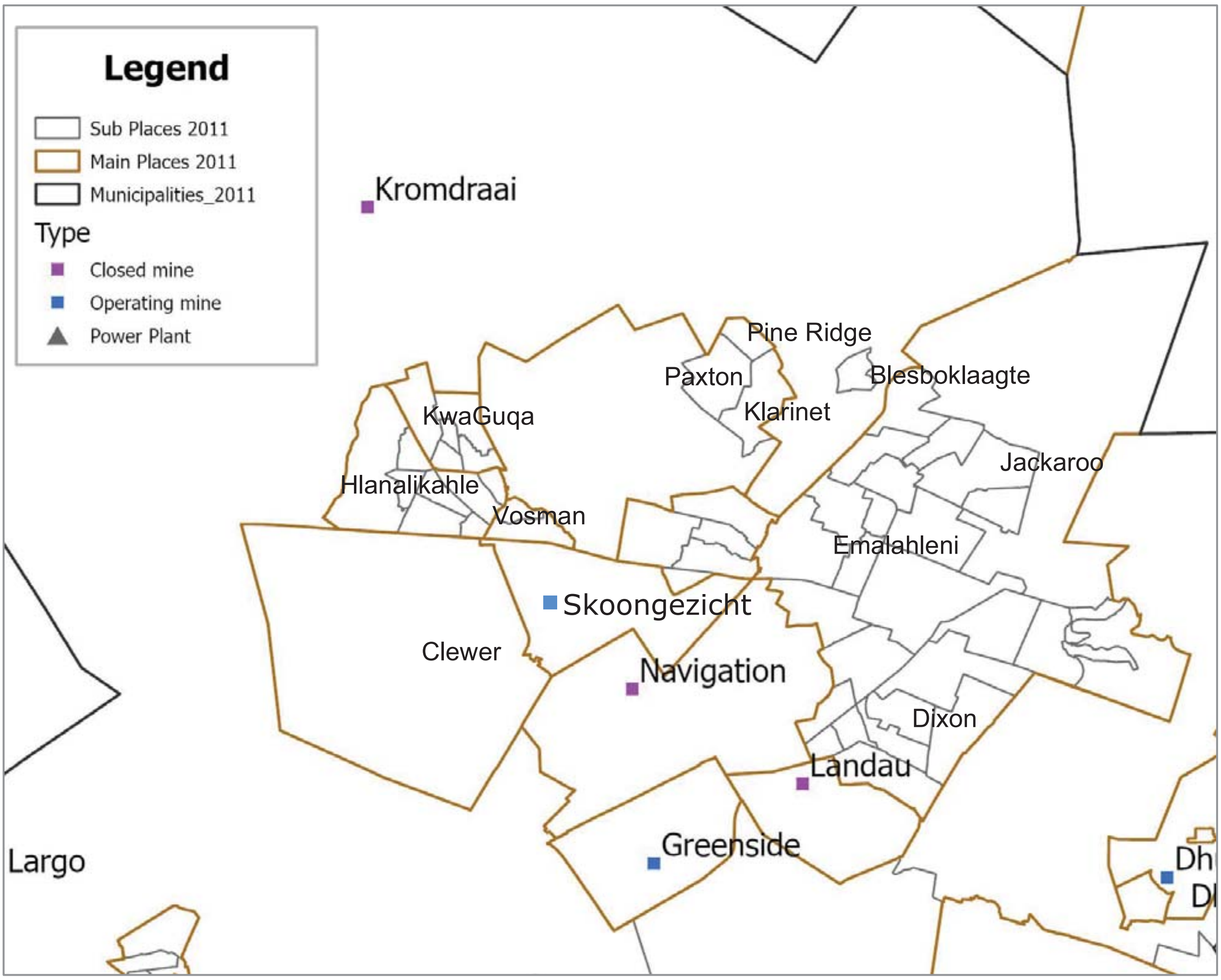


Figure 3.30 Map of communities and mines in the Emalahleni case study area

Table 3.15 Socio-economic indicators for communities in the Emalahleni area in 2011

SDG	SDG indicator	Emalahleni LM	Emalahleni city	Townships	Towns	Agricultural holdings
1	Annual household income (% above R19,600/year)	67.2	81.1	74.8	69.3	85.6
1	Household goods (% fridge ownership)	63.9	84.5	30.8	67.3	87.7
3	Health (% with no disability)	72.5	89.6	72.3	87.1	87.6
4	Education (% with Grade 12 or above)	46.0	29.7	36.9	27.9	26.0
6	Water access (% tap water in home/yard)	80.3	93.9	67.9	93.0	97.5
6	Sanitation (% access to toilet)	71.5	93.9	67.9	93.0	97.5
7	Electricity access (%)	79.4	93.8	73.0	93.7	98.0
7	Clean cooking fuel (%)	78.5	93.8	73.2	93.8	97.6
8	Employment (% labour force)	69.2	86.5	61.6	68.6	86.0
11	Formal housing (%)	82.7	89.8	76.6	92.5	98.5
11	Refuse removal (% municipal)	74.8	93.0	68.5	90.3	73.4
17	Internet access (%)	38.6	62.5	31.1	41.5	66.8
	Overall score	*6.2*	*7.5*	*5.7*	*6.9*	*7.7*

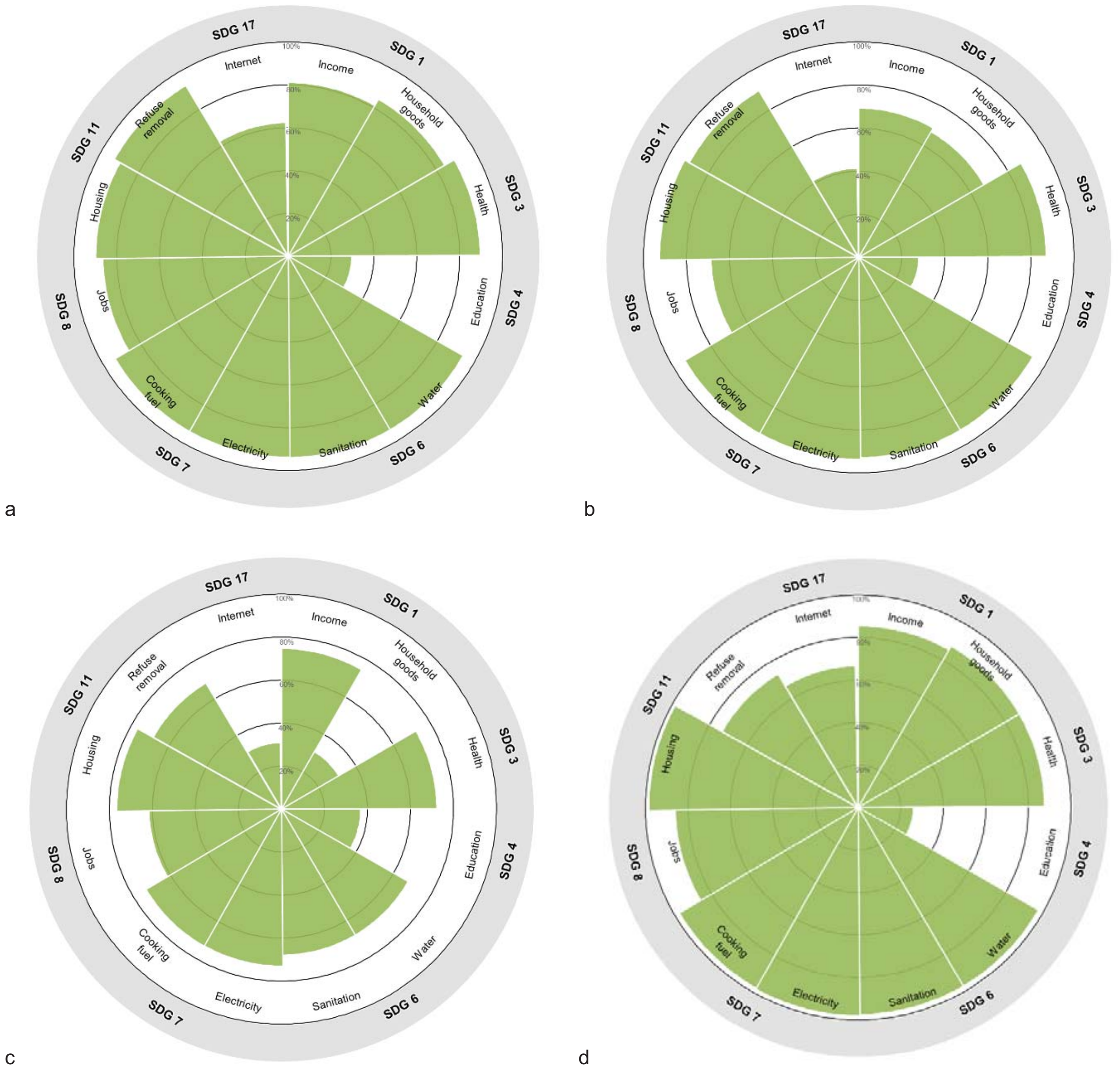


Figure 3.31 Socio-economic barometers for a) Emalahleni city, b) towns, c) townships and d) agricultural holdings in the Emalahleni case study in 2011

3.4.3 Environmental impacts and risks

The intense mining activities in the Witbank area have had a significant impact on the environment.

Land

South Africa is a semi-arid country with very limited rain-fed arable land – only 13% of the total land area (Collett, 2019). The Emalahleni area, however, is well endowed with high rainfall and moderate and high potential arable land (Figure 3.22). Despite this, only 25% of the area is cultivated and agriculture currently accounts for only 1% of Emalahleni's gross value add due to the dominance of coal mining and power generation (Emalahleni Local Municipality, 2021). Figure 3.33 shows the current land uses around Khwezela colliery. Agricultural holdings, found on the periphery of the urban settlements are often not used for agricultural activities but for residential purposes or service industries. Intensive crop farming is mainly concentrated in the areas to the south of the N4 freeway while cattle and limited game farming mostly located to the north of the N4. This municipality is thus characterised by conflicting demand between mining, electricity generation and agriculture, and the encroachment of mining onto high potential agricultural land and areas of high biodiversity presents a major risk to the area (Emalahleni Local Municipality, 2021).

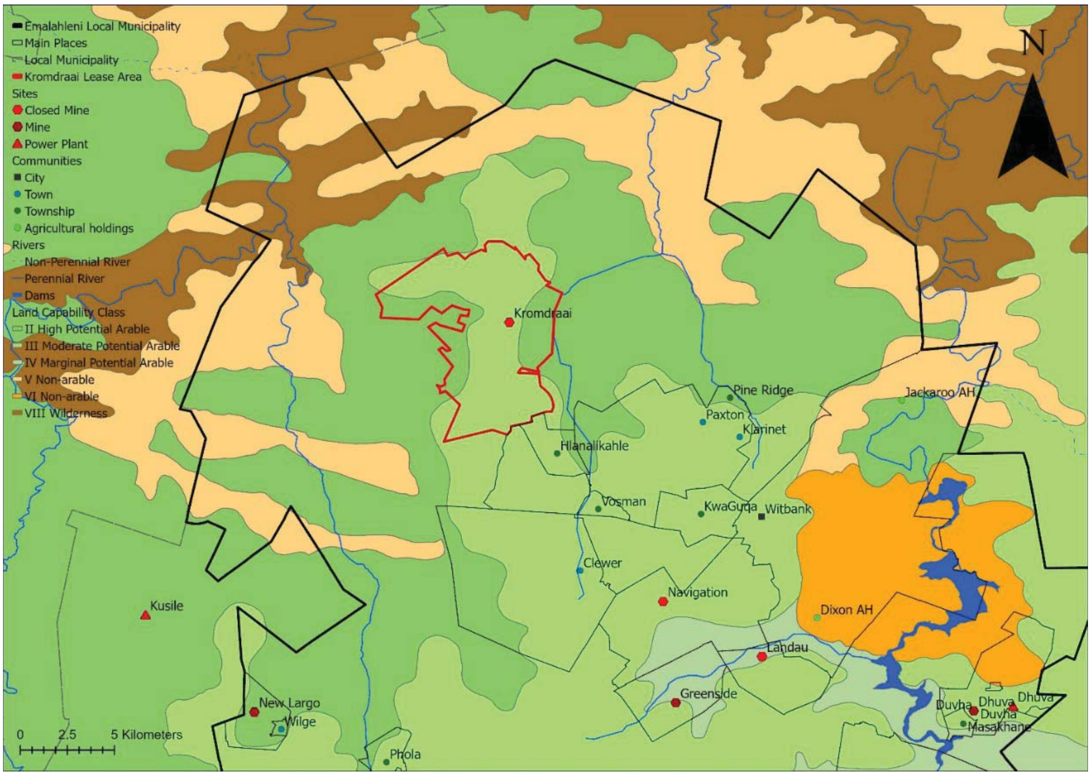


Figure 3.32 Land capability and water resources in the Emalahleni case study area

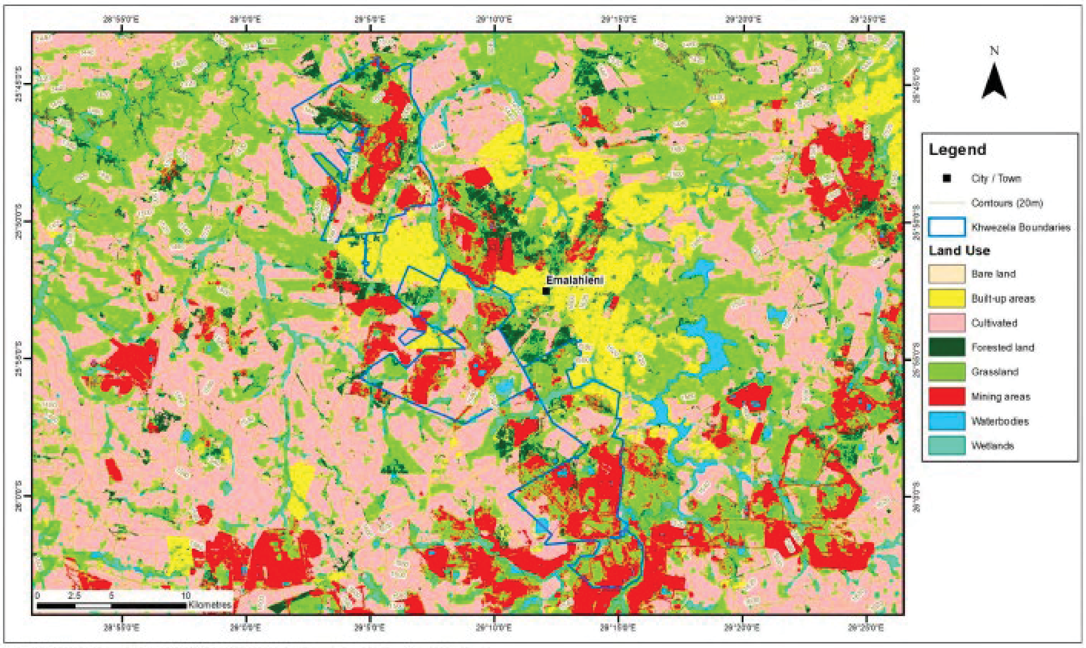


Figure 3.33 Land use around Khwezela colliery (SRK, 2021)

Water

Emalahleni sits within the B11D quaternary catchment in the Wilge River catchment in the Upper Olifants sub Water Management Area. It receives 671 mm of rain per year. The main rivers in the area are the Klein-Olifants River, Olifants River, Wilge River and Rietspruit River, Saalklapspruit, Steenkoolspruit and Blesbokspruit (Emalahleni Local Municipality, 2015) which feed the Olifants River, a major tributary of the Limpopo River and feeds into more than 30 major dams, 30 minor dams and up to 4,000 small private farm dams (DWS, 2017), and services many irrigation schemes, including Loskop. Prominent dams in the LM are the Rietspruit Dam, Doringpoort Dam, and Emalahleni Dam (formerly Witbank dam). A wetland system with peat bogs occurs south-east of Emalahleni (Figure 3.34).

The Olifants River is the main source of surface water supply to the municipality, supplying more 70% of municipal water provision capacity (Emalahleni Local Municipality, 2021). The municipality has largely been unable to exploit underground water resources due to underground coal mining which results to generation and decanting of acid mine drainage (Emalahleni Local Municipality, 2021). Groundwater users in the vicinity of Navigation pit are largely limited to homesteads and smallholdings that abstract water for domestic use purposes. ELM has three municipal water supply schemes (Witbank, Rietspruit and GaNala) and three external schemes (Anglo American, Glencore and Eskom Kendal) responsible for bulk water provision. The municipality also has a modular package plant which is used to augment Witbank scheme. The Emalahleni Water Reclamation Plant EWRP (located on Greenside Colliery's northern edge) is shared between Greenside, Khwezela and South African Energy Coal Ltd's (SAEC) South Witbank Colliery. It has the dual benefit of treating mine water and providing provides potable water to Emalahleni (Broadhurst, 2019).

Water use in the Olifants River Catchment has increased dramatically in recent years due to mining, electricity production, large scale irrigation schemes for agriculture, and urban development (DWS, 2016), making it a water stressed area. Water resources in the catchment have been severely degraded and polluted by mining, power generation, commercial agriculture, and untreated industrial and municipal wastewater, with acid mine drainage (AMD) caused by mining is a particularly serious problem (Centre for Environmental Rights, 2019).

In recent years the area has faced severe drought and occasional flash floods, and climate change is a major concern for the catchment. Rainfall in the Olifants catchment has decreased over the last 60 years, and is expected to continue this trend, making the largely surface water supply very vulnerable (DWA, 2007).

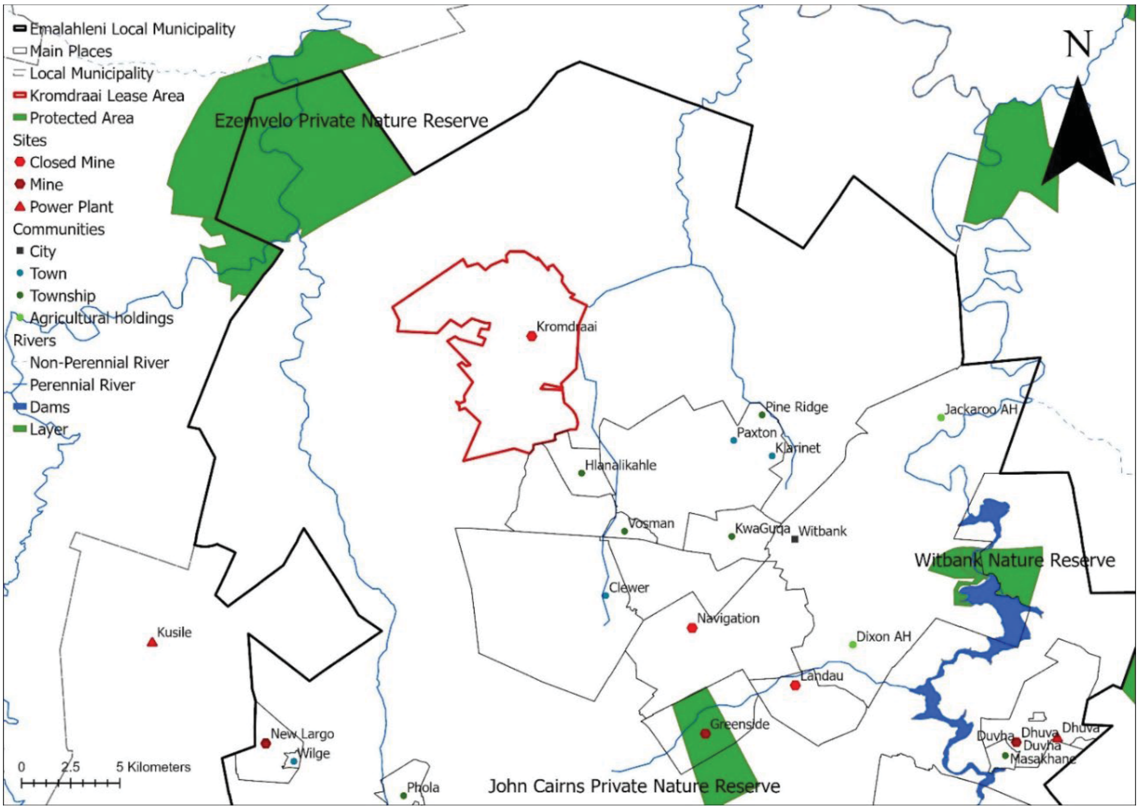


Figure 3.34 Rivers, dams, wetlands, nature reserves and protected areas near Kromdraai

Biodiversity

The natural vegetation cover in most of Emalahleni LM is Bankenveld, with Mixed Bushveld and Sourish Mixed Bushveld veld types present along the far-northern extents of the municipality. Emalahleni LM has limited threatened fauna and flora species, with only five Red Data species recorded (Emalahleni Local Municipality, 2015). Several floodplain wetlands, seepage wetlands, and endorheic pans occur within the municipal area, and the wetland system with peat bogs in the Tasbet/ Duvha area is extremely valuable and sensitive. An ecological/ natural corridor spans across the north-eastern extents of the municipal area, which contain the largest concentration of Irreplaceable Critical Biodiversity Areas – especially along the drainage lines of the Olifants River and Saalboom Spruit. The majority part of the municipal area is however classified “Heavily Modified”. Within the ELM, 82.91% of the river signatures are considered critically endangered (few remaining intact examples), with the remaining 17.03% considered to be endangered (Emalahleni Local Municipality, 2021).

The most significant conservation area is the Witbank Nature Reserve, originally established as a recreation resort around the Witbank Dam and proclaimed as a nature reserve on recommendation of the former Witbank City Council in 1979. The reserve comprises two clearly distinguishable areas, namely the arboreous area along the Olifants River and the Highveld grassland area. Around the year 2010 it was enlarged to cover an area of about 1,600 ha of land. The reserve has Rocky Highveld Grassland veld type and only 1.38% of this veld type is presently protected in provincial or municipal nature reserves throughout Mpumalanga and Gauteng (Emalahleni Local Municipality, 2015). Other reserves include the Ezemvelo Game Reserve in the far north-western parts of the Municipality, the John Cairns private nature reserve and the Umlalazi Nature Reserve has been established at Khwezela North, where red data plant species such as the succulent Frithia humilis can be found. The maintenance and promotion of the Witbank Nature Reserve and Ezemvelo Nature are cited as potential tourist sites (Emalahleni Local Municipality, 2021).

Air pollution

In 2007 the Emalahleni area was declared the second National Air Quality Priority Area in South Africa (see Figure 3.35) due to concern over air pollution from the coal mines, metal smelters and coal-fired power plants. Industrial sources in total are by far the largest contributor of emissions in the HPA, accounting for 89% of PM10, 90% of NOx and 99% of SO_2 (DEA, 2012). About half of the annual emissions of fine particulate matter (PM10) in the area is attributed to opencast mine haul roads, while the primary metallurgical industry accounts for 17% and power generation accounts for 12% (DEA, 2012). By contrast, power generation contributes 73% of the total estimated NOx emissions and 82% of the total estimated SO_2 emissions. There are five functional air quality stations within this Highveld Priority Area. Witbank is one of nine hotspots and has the highest SO_2 concentrations and often exceeds the PM10 standard of 40 ug/m^3 (see Figure 3.36 and Figure 3.37).

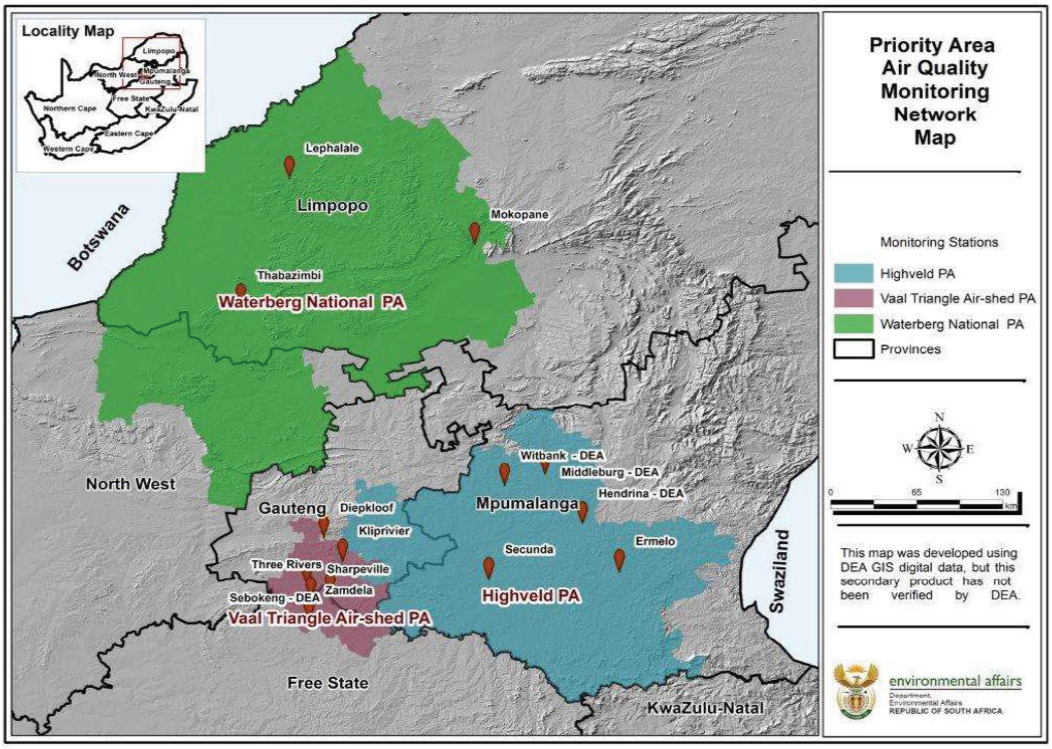


Figure 3.35 National Air Quality Priority Areas and monitoring stations (DEA, 2019)

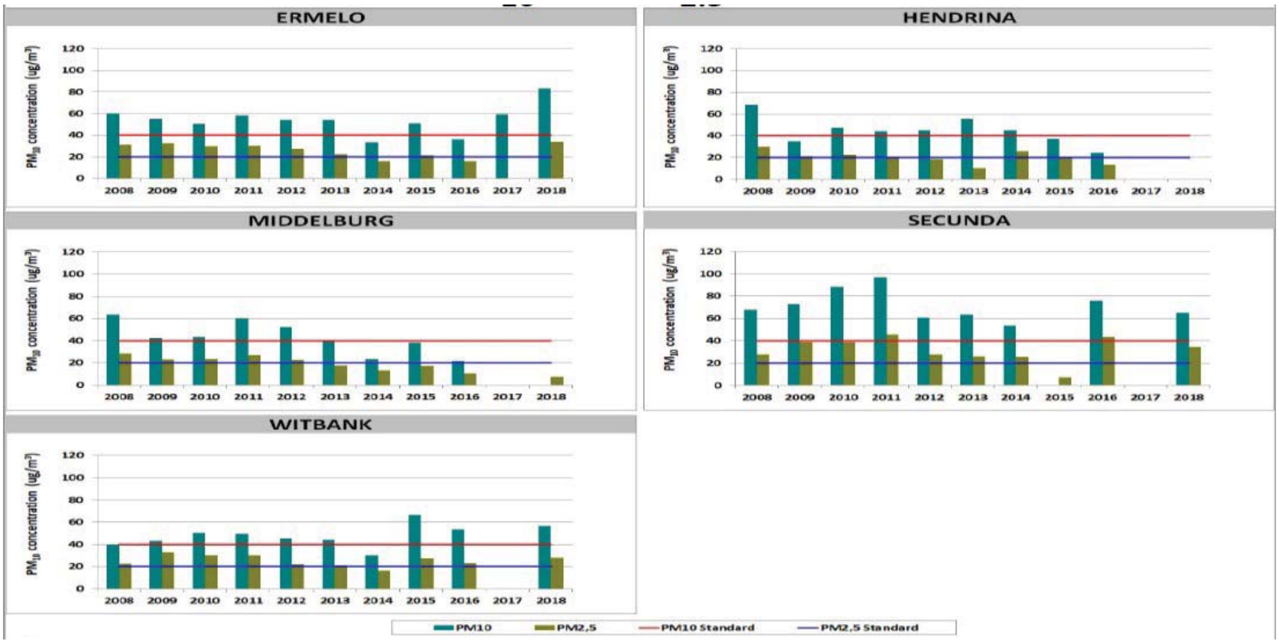


Figure 3.36 Air quality monitoring of PM10 and PM 2.5 in the Highveld Priority Area (DEA, 2019)

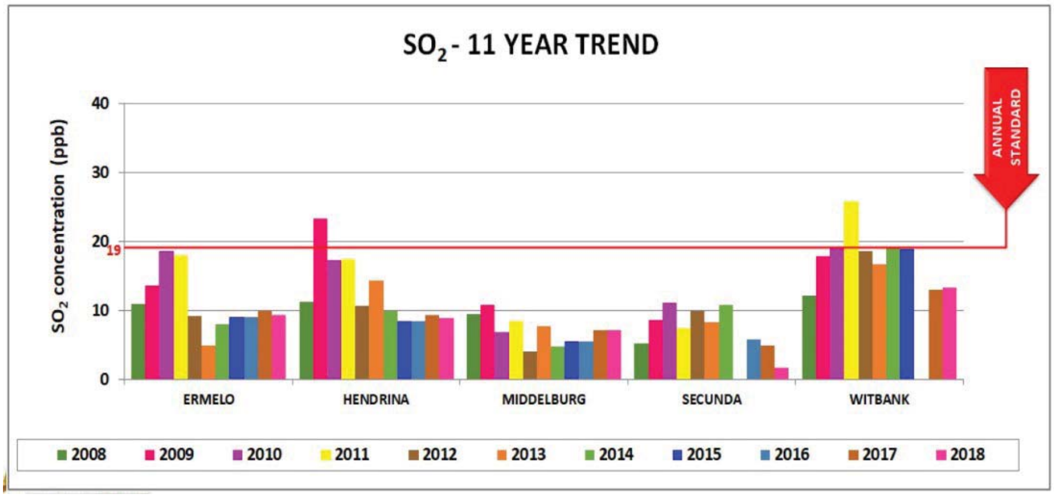


Figure 3.37 Air quality monitoring of SO_2 in the Highveld Priority Area (DEA, 2019)

Waste

The Mpumalanga coalfields are characterised by large deposits of waste which are generated during the various stages in material chain, including mining, processing and combustion. Surface mining requires removal of large quantities of rock and soil to access the coal seam. The material used to cover the uppermost coal seam is termed overburden, whilst material separating coal seams within strata is termed interburden. Both overburden and interburden are also commonly referred to as coal waste rock or coal spoils, and although comprised mainly of rock and soil, can also contain significant quantities of pyrite, coal, soluble salts, and metals. Coal mine spoils are typically stockpiled in waste rock dumps which are then rehabilitated in-situ or after replacement in mine voids (backfill). However, the high salt content of coal mine spoils tends to limit plant growth as a result of both saline seepage in wet seasons and upward salt movement during dry seasons, creating challenges in the rehabilitation of these dumps. Weathering of abandoned or poorly rehabilitated coal waste rock dumps spoils are frequently associated with adverse environmental impacts such as acid mine drainage, salinisation and, in some instances, spontaneous combustion (Hilton et al., 2019; Welch et al., 2021).

Washing of the run-of-mine (ROM) coal generates coal discards and ultra-fine slurry. Approximately 20-22% of the ROM coal deports as wastes, the majority of which is in the form of discards and 4-6% is in the form of ultra-fine slurry (SACRM, 2011). Historically these wastes were largely land-disposed, with the slurry from the thickener underflow being largely deposited in surface slurry dams on discard dumps, which have been estimated to occupy more than 4,000 ha of land in the Mpumalanga coalfields (DMRE, 2001). These dumps have had a significant impact on the local environment. According to the Department of Mineral Resources and Energy (DMRE, 2001) “old discard dumps in South Africa are one of the greatest polluters of the environment, polluting the atmosphere, rivers, groundwater and the aesthetics of the countryside”. Environmental impacts from discard dumps and slurry dams can be largely attributed to the formation and dispersion of acid mine drainage, spontaneous combustion and associated emission of gaseous pollutants, and the windborne dispersion of fine coal dust. These impacts are aggravated by the fact that old and abandoned dams were frequently located close to, and even within, water courses and/or directly on topsoil. Sustainable rehabilitation of these dumps is extremely difficult due to their physical instability, steep slopes and geochemical properties (DMRE, 2001). As national environmental regulations have become more stringent, so the methods of disposal for coal processing wastes have improved. Most discard dumps are now designed to minimise spontaneous combustion and environmental pollution, through compaction, collection of seepage and rehabilitation using topsoil and revegetation, whilst ultra-fine slurry wastes are commonly dewatered in dewatered in filtered presses and co-disposed with discards in an integrated manner (SACRM, 2011). Many collieries are reprocessing their older discards to extract a low-grade steam coal, mainly for use in local power stations (de Korte, 2004). The effectiveness of many of these methods to generate a self-sustaining and non-polluting over the long-term is yet to be proven, whilst many abandoned discard dumps remain unrehabilitated.

Fly ash, also known as pulverised fuel ash, accounts for almost 90% of the total coal combustion ash generated by the national electricity provider, ESKOM. Recent figures quoted by ESKOM put the total annual ash generation at 25 Mt, which is lower than the 33-36 Mta reported previously (Schutte, 2017). With its pozzolanic properties, fly-ash has a number of potential uses, particularly in the construction industry, and its commercial application has been gathering momentum worldwide. In South Africa, however, only 6-8% of the fly-ash is sold for downstream application (Shutte, 2017), with the majority being disposed of together with coarse ash dumps or as a slurry in ash dams close to the power stations; the latter method being largely practised at older power stations. This is largely because the ash dams and dumps play an important role in compliance with Eskom’s water management strategy, serving as a sink for saline effluents and poor quality water. Whilst fly-ash is mostly considered a relatively low environmental risk, concerns have been expressed over the long-term leaching of metals and salts and pollution of groundwaters from unlined dams, whilst wind dispersion of the fine air-dried fly ash can result in significant air pollution (Reynolds-Clausen and Singh, 2019). Rehabilitation of Eskom ash dumps involves the covering of the ash dumps with fertile soil and the planting of grass and trees. It is also reported that ash from dumps is used to backfill mine voids. At some power stations, the ash is back-stacked onto the area from where the coal was mined (open cast mining).

Spontaneous combustion of coal discard heaps and release toxic compounds including carbon monoxide, carbon dioxide, methane, benzenes, toluenes and xylenes, as well as sulphur, sulphur compounds, salammoniac, arsenic, mercury and lead (Hota and Behera, 2015). There are four Mineral Residue Deposits at Khwezela Colliery and at present opportunities for their exploitation are being examined by Thungela.

3.4.4 Land use opportunities

The Green Engine project

The Green Engine project aims to design a post-mining circular economy by forming symbiotic linkages through various industries/initiatives. It is centred around Thungela's Kromdraai mine, which stopped operations in 2020. The project was launched by Anglo American in 2017 and aims to reduce the liabilities associated with rehabilitation, water and socio-economic impacts, by creating an agri-industrial hub to support the local community beyond the life of mine (The Green Engine, 2018). Based on the post-mining land capability various land opportunities have been identified around re-purposing mine waste, renewables, bio-energy and agriculture and Figure 3.38 shows the various Green Engine activities earmarked around the site based on land suitability.

The project is currently in the feasibility phase and is focusing on the use of mine impacted land for agriculture for the production of bio-energy, fibre-rich or high oil-containing plants as well as investigating the potential to use less energy intensive water treatment systems to produce fit-for-purpose water suitable for crops (Anglo American, 2019b). Areas not suitable for agriculture due to topsoil deficiency have been earmarked for solar PV systems and the re-purposing or treatment of waste streams such as coal discard and tyres are also being planned (Muhlbauer, 2019). Based on post-mining land use classifications by various authors (Narrei and Osanloo, 2011; Mborah et al., 2016; Kivinen, 2017; Manero et al., 2020; Holcombe and Keenan, 2020), Table 3.16 shows a summary of the land use categories and intended activities. Most of the activities planned for the site are centred around agricultural and industrial opportunities. Figure 3.39 shows a conceptual flowsheet of the integrated activities planned for the site (Muhlbauer, 2019).

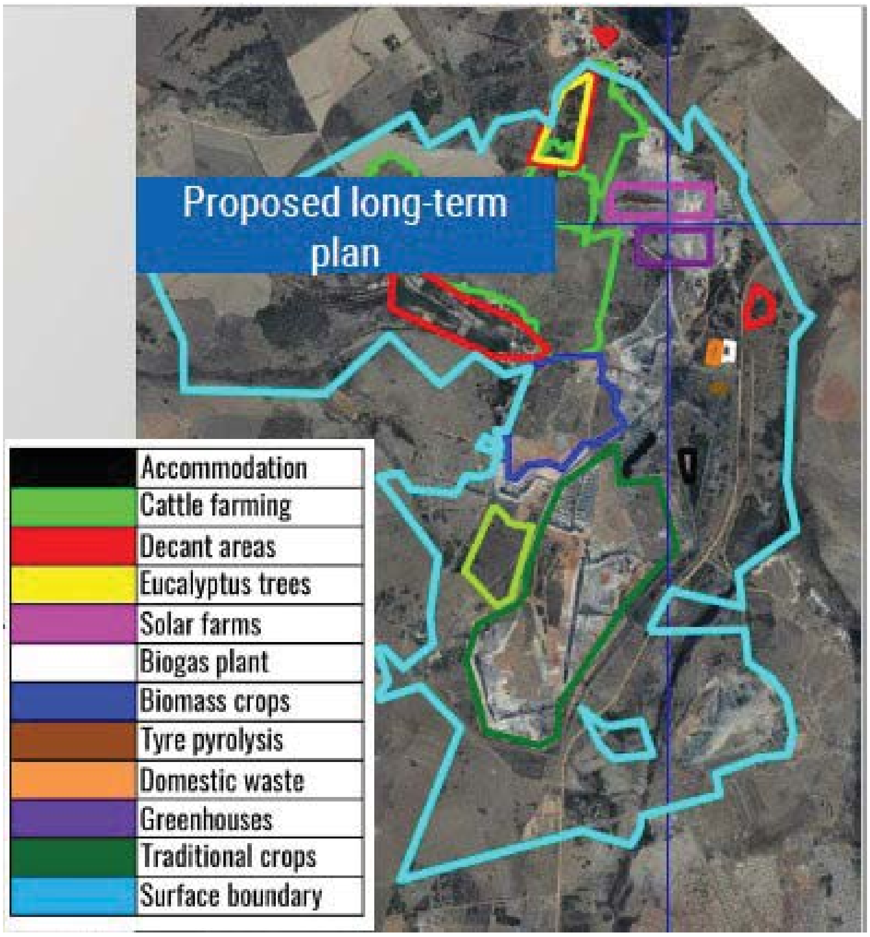


Figure 3.38 Map of proposed Green Engine projects around Kromdraai mine (Anglo American, 2019)

Table 3.16 Land use opportunities for the Green Engine project

Land use category	Description
Agriculture	Cattle farming, eucalyptus trees, biomass crops, traditional crops, animal fodder, greenhouses
Industrial	Biogas plant, Tyre pyrolysis, Waste recycling
Renewable energy	Solar PV plants
Forestry	Commercial forestry
Water reservoir	Existing dam, water catchment areas , water treatment plant
Community & culture facilities	Accommodation
Conservation	Nature reserves, Protected sites

This project particularly gives an important perspective for post-mining initiatives in South Africa as it sits at the nexus of post-mining and energy transitions. The Green Engine project's multi-dimensional land, water, energy and waste post-mining approach give insights on potential post-mining approaches for coal mining regions. Short term plans at the site include vertical greenhouses (see Figure 3.40), where produce is farmed in upright stacks, using less land and water than traditional farming and producing vegetables and herbs for export, with scope for multiple greenhouses on the site (Anglo American, 2019b).

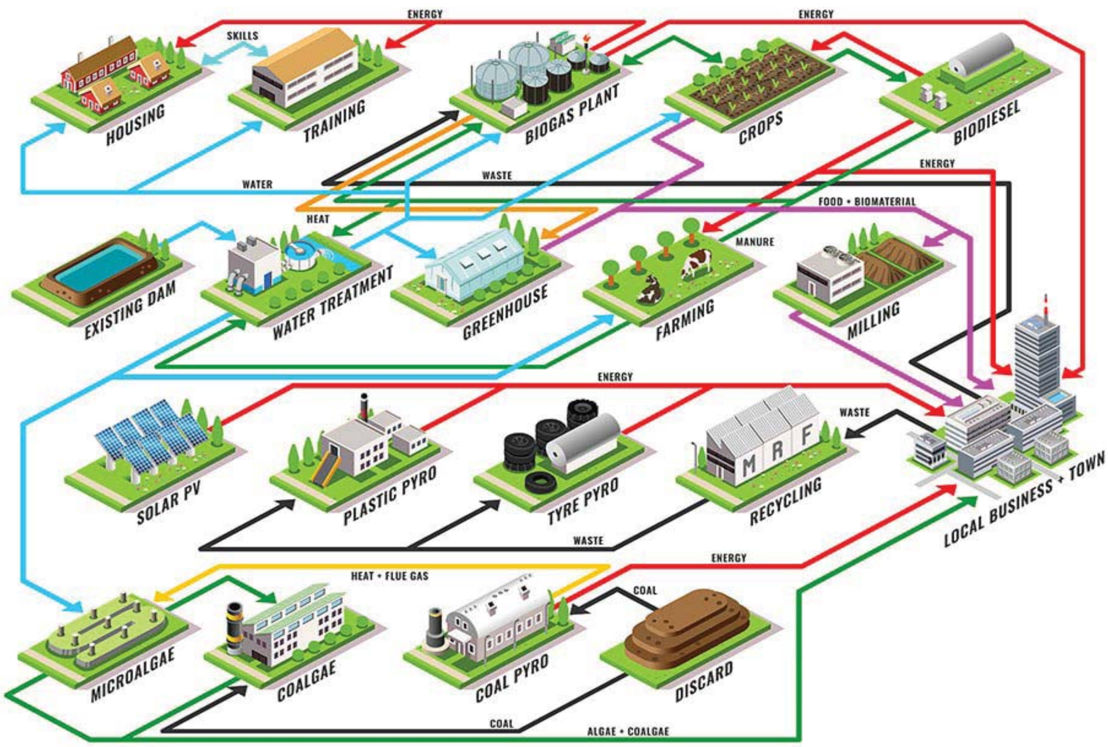


Figure 1.39 Green Engine industrial hub concept (Muhlbauer, 2019)

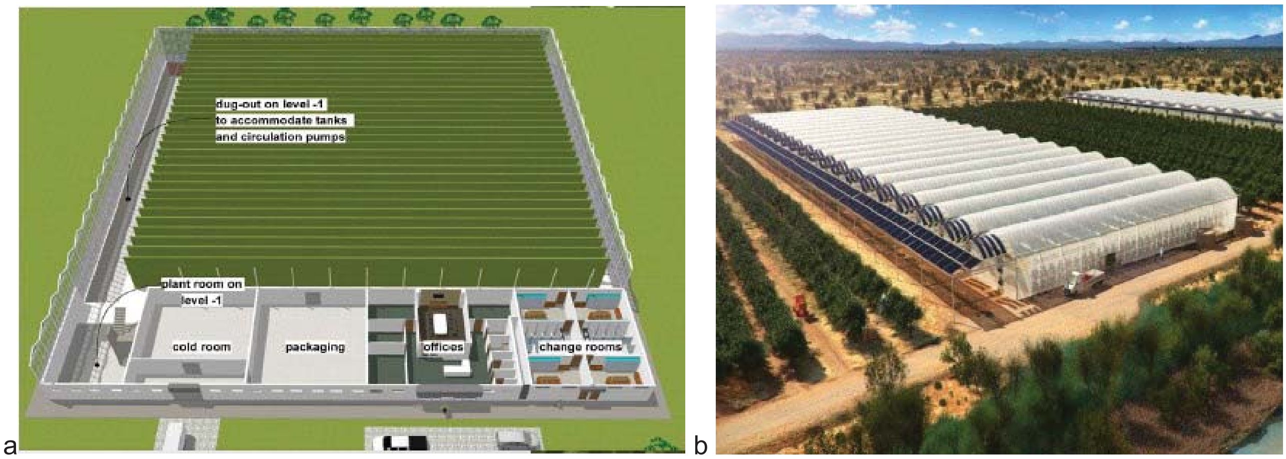


Figure 2.40 Green Engine greenhouse conceptual layouts (Muhlbauer, 2019)

This project presents an opportunity to understand the risks associated with an approach that integrates post-mining land use, water treatment, waste management and industrial development. The project also has proposed plans to collaborate with other impacted mine sites in the region to build partnerships around post-mining land use, water, waste and renewable energy initiatives. As mentioned, Khwezela has numerous neighbouring mines, owned by Thungela and other mining companies (see Figure 3.41). These companies can work together to develop a regional approach to post-closure land use. It is therefore important to understand what the other mines and companies are planning to do. Table 3.18 summarises the SLPs of all the mines in the area. The SLP projects must align with the LMs IDP. Current key LED projects identified in the IDP for 2021-2022 include the development of a mining and metals technology park, resuscitation of township economies, establishment of mining museum and convention centre, revitalisation of Witbank Dam through a private-public partnership model, and support for SMMEs and co-operatives, increasing the municipal skills base and accelerating internet access (Emalahleni Local Municipality, 2021). The development of a green economy and promoting a digital economy have also been identified as emerging development areas for the municipality (Emalahleni Local Municipality, 2021). It is important to note that some of the SLP projects address LED projects in other municipalities in the Nkalanga district municipality as that is where some of their labour force lives. Many of the current projects are focused on education and skills development, infrastructure and services. There is increasing effort to support SMME development, however many SMMEs are still largely focused on mining-related supplier businesses, with only a few related to diversifying the economy through farming and other land-use opportunities, and non-mining related businesses.

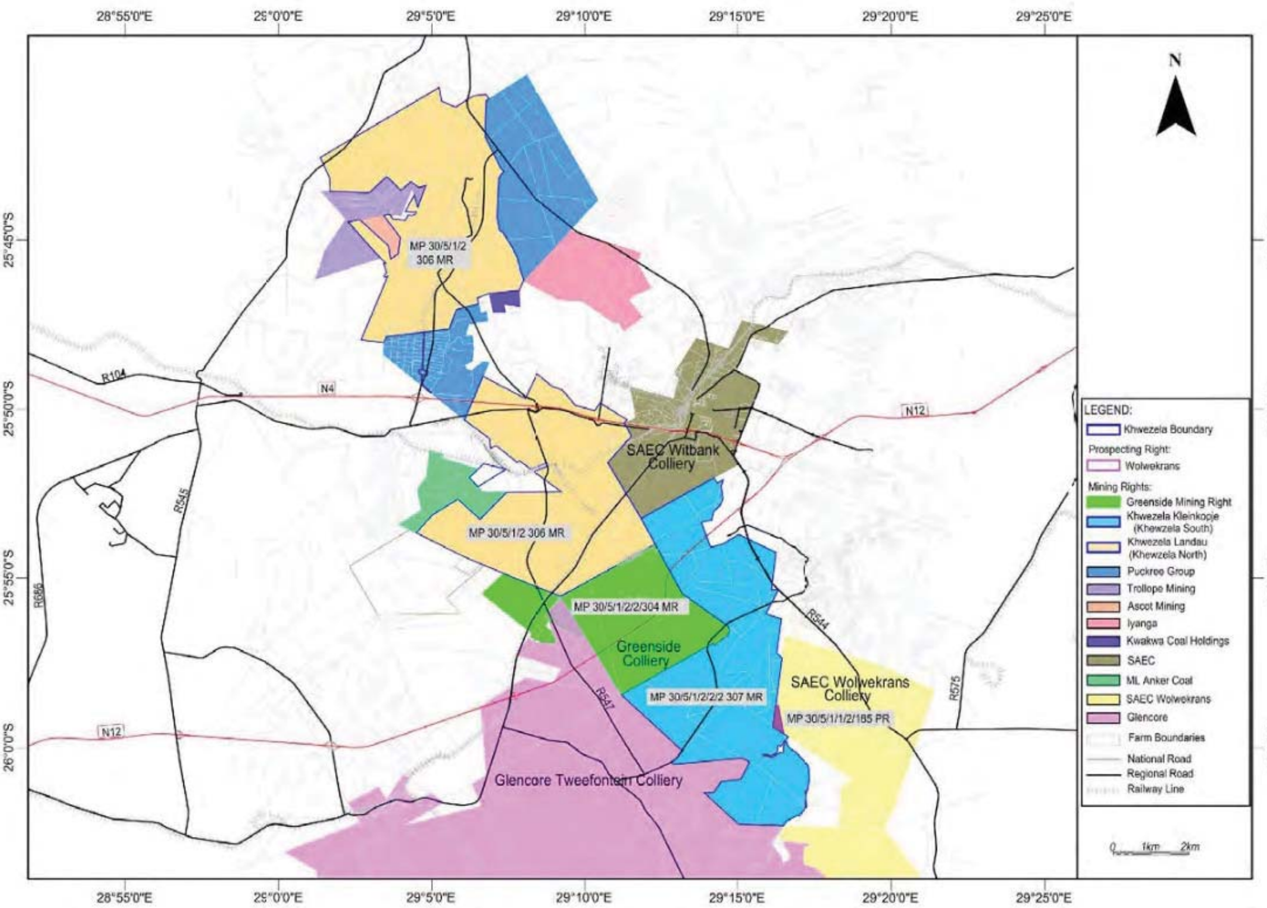


Figure 3.41 Mines adjacent to Khwezela Colliery (SRK, 2021)

Electricity generation

Emalahleni LM's electricity is mostly generated from coal-fired power plants, enabling it to supply most of its formal households. However, several power stations are expected to close in the next 10 to 15 years – Matla is expected to close in 2029, Duvha in 2030 and Kendal in 2038. The municipal's electricity distribution is challenged with old infrastructure, increased demand due to expanding settlements, and illegal connections which cause outages (Emalahleni Local Municipality, 2021). As the population has grown, particularly in informal settlements, energy demand has increased, and in 2016 about more than 25% of households were not connected to the grid. The high solar irradiation potential of the area presents an opportunity to explore solar power as an opportunity to meet rising demand from industry and communities, and a clean alternative to coal. The Phase 2 Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa in 2019 identified Emalahleni as a Renewable Energy Development Zone for large potential scale solar PV energy development (DFFE, 2021). However, the competition for land use with agriculture would have to be considered as much of the high irradiation areas overlap with moderate to high potential arable land.

The amendment to Schedule 2 of the Electricity Regulation Act of 2006, gazetted by the Department of Mineral Resources and Energy in August 2021, allows Eskom to sell or lease its properties close to its existing power stations, with established grid infrastructure, to the private sector, enabling the development of renewable plants up to 100 MW, in support of President Ramaphosa's call for "an ambitious, bold and urgent response to the energy crisis" (Eskom, 2021). This 100 MW cap has since been lifted. The commercial process is based on auctioning lucrative renewable generation sites, with the evaluation process favouring quick delivery of large capacity to the system. This presents an opportunity to transition towards cleaner sources of electricity generation whilst benefitting from the existing Transmission and Distribution line infrastructure and creating additional generation capacity at minimal cost. This also helps to support the Just Energy Transition through the creation of new economic activity and jobs, where several coal power stations are due to be shut down.

Tourism

The Emalahleni LM has identified several cultural heritage sites, historical buildings and structures as potential heritage assets (Table 3.17), which could increase the tourism potential but are currently under threat from rapid development (Emalahleni Local Municipality, 2015). The area around the Witbank Dam was identified as a Tourism Product Development Nodes in Mpumalanga Province, for the development of a Theme/Amusement Park.

Table 3.17 Potential cultural heritage sites, historical buildings in Emalahleni LM (Emalahleni Local Municipality, 2015)

Potential sites	Description
Cultural Heritage Sites	Battle of Bakenlaagte site (Nooitgedacht and Kruisementfontein Farms, south of eMalahleni) Clewer railway station Roodebloem farmstead
Historical buildings & structures	King George Park eMalahleni power station eMalahleni station NZASM/ CSAR 'Type' houses Old Athlone Hotel
Kwa-Guqa historic mine town	Migrant labour history on the mines African and Indian trade history in eMalahleni history of the former Bantu Administration board system (e.g. the Ematrokisini hostel, old rondavel houses) history of the African independent churches, e.g. Church Street in Kwa-Guqa

Water supply

The treatment and reuse of mine water could help Emalahleni Local Municipality address water challenges and growing demand. While the municipality faces challenges around water scarcity, the mines in the area on the other hand are facing issues around excess ingress groundwater contaminated with high levels of salt and metals, and often highly acidic (Garner et al., 2012; Broadhurst, 2019; Grewar, 2019). To deal with mine water treatment and water scarcity challenges in eMalahleni, the Emalahleni Water Reclamation Project (EWRP) was commissioned in 2007 in partnership with Anglo American's Coal division (now Thungela), BHP's South Witbank Colliery (now owned by Seriti) and the Emalahleni Local Municipality. The EWRP plant utilizes treatment technologies including lime neutralisation, ultrafiltration and reverse osmosis to produce potable water from the mine effluent (Garner et al., 2012; Grewar, 2019). The plant has pipelines from the participating Thungela and Seriti mines, feed water dams, a water treatment plant (44.6 ML/day capacity) and a reservoir (SRK, 2021). The treated water is then supplied to the mines and supplies around 12% of eMalahleni city's daily water needs (Garner et al., 2012; SRK, 2021). The EWRP plant is partly financed by the selling of potable water to the municipality and has an offtake agreement for its gypsum waste stream with Africa Lime Industries and is also currently assessing options for increasing brine waste storage capacity, as well as opportunities for offtake agreements for its crystallised brine (SRK, 2021). The plant is however faced with high operating costs, challenges around brine waste storage and variable feed water quality from the mines (SRK, 2021). Some studies have shown that treating mine water decant to lower quality levels (such as water for irrigation or water for other industrial activities), can lead to significant reduction in running costs (Annandale, 2007; Broadhurst, 2019; Grewar, 2019).

Pilot studies in various areas of Mpumalanga's coalfields have also shown that using mine water for irrigation for crops is technically feasible (Annandale et al., 2007, 2009, 2017; Grewar, 2019). In 2018, a pilot semi-passive water treatment project at Khwezela demonstrated positive results in reducing levels of sulphates and acidity, producing treated effluent that is suitable for the irrigation of crops (Anglo American, 2019a). At Thungela's Mafube mine a pilot to test the viability of growing crops on mine impacted land and assess the usage of mine water for irrigation is currently producing initial maize yields which are 80% larger than a typical crop, showing the high potential for using mine water for irrigation (Anglo American, 2019b; Ronquest, 2019; Gourley, 2020). Glencore's winter wheat mine water irrigation project started its first pilot in April 2021 and ran until January 2022 to experiment with a variety of winter wheat on land at Wonderfontein colliery and on land at two nearby sites owned by the community. The pilot confirmed that winter wheat can be grown successfully, and that rehabilitated mine land and mine water can be used to grow and irrigate crops (Glencore, 2022). The positive results from some of these pilot project show the opportunity to lower mine water treatment costs and use mine-impacted water for irrigation, which can potentially address challenges around the water-energy-food nexus as Emalahleni contends with coal-mining impacts on land and water, and water scarcity.

Emalahleni LM's IDP highlights key areas to promote LED which include SMME support, the development of emerging farmers, tourism development, job creation and programmes to address various pockets of poverty (Emalahleni Local Municipality, 2018). Despite efforts to accelerate these various areas a review of the LED projects and programmes in 2017 showed that more than 80% of the projects from the previous LED strategy were not implemented (Emalahleni Local Municipality, 2018).

A progressive approach to rehabilitation is being undertaken at Khwezela's currently operational Navigation pit and the Green Engine project is part of the post-closure development at mined out Kromdraai. The Green Engine project is however facing various challenges due to vandalism and illegal mining (SRK, 2021). Due to the adjacency of collieries around Khwezela there is an opportunity to integrate the closure activity and reduce liabilities. This may result in a post-closure land capability that offers more opportunities to potential post-mining land users (SRK, 2021). If integration is undertaken, there may also be an opportunity to consolidate post-closure water management plans and benefit from economies of scale as well as reduce the number of management systems (SRK, 2021). Currently the closure and post-mining plans of most of the collieries in the area focus largely on rehabilitation to grazing, wilderness or arable land – see Table 3.18.

Table 3.18 Local economic development projects in mining company Social and Labour Plans

Colliery & Company	Local Economic Development projects				
	Land	**Enterprise development**	**Infrastructure**	**Services**	**Education & Skills development**
Khwezela North - Thungela	Green Engine project. Emalahleni.	Zimele SMME Emalahleni business support. Zimele supplier development in Emalahleni. ongoing since 2018.	Clewer multi-purpose community hall. Clewer, Emalahleni. R4.4m. 2019-2022.	Integrated waste management programme mini transfer station. Emalahleni Municipality	Community scholarship: Financial assistance for scholar for University, Technicon and TVET. Emalahleni. Community skills development and capacity building. School education programme.
Zibulo - Thungela, South32	Green City Project - Environmental and enterprise development projects; includes beautification, cleaning and greening of Phola parks and entrances.	SMME development – capacity and skills development for NGO administrators, SMMEs and youth owned businesses.	Phola Fire Station upgrade: disaster management centre and capacity building of fire department in Phola. Phola taxi rank project	Health facility support: Support for Leandra community clinics and programs, substance abuse and local welfare support organisations.	Education, school upgrades and training programs - Mabande School upgrades, Community Scholarship scheme, Programs to improve municipal capacity to meet water challenges in Phola and Ogies. Youth Community training.
Greenside - Thungela	Support commercial farming of potatoes with SIMBA guaranteeing uptake. Funding of equipment and support to community agro-processing businesses, community enterprise to be formed to run with structure.	Commercial farming project support to be linked to Zimele initiative.	Community lighting: purchasing of solar high mast streetlights for communities. Township Economic Regeneration - industrial Park infrastructure	Road maintenance: pothole patching machine. Sanitation: sewer machine. Health care: obstetrician ambulance for Department of Health.	Community skills development and capacity building - focusing on machine operator and portable skills. Community scholarship - bursary scheme for University, Technicon & TVET.
Goedehoop North - Thungela, Exxaro		SMME support: Building an industrial park that will develop SMME's from Mhluzi community within the Steve Tshwete Local Municipality.	Industrial park for SMMEs (see next column) Water supply sustainability: boreholes and tanks.	Ward 4 Mobile Clinic.	Municipal capacity building project. Skills development - workshops focusing on educators, school management Teams and NGO administrators.
Matla - Exxaro		Enterprise and Supplier Development centre - Business development centre for 15 SMMEs, including business mentoring and skills support to be contracted to Raizcorp. SMME workshop - production area with office space and facilities for 5 small businesses for light manufacturing activity, e.g. sewing, upholstery, leather goods manufacturing as part of support to develop industrial parks.	Bonginhlanhla School - entire school infrastructure overhaul development.	Ga-Nala Landfill Site - upgrade landfill site to ensure the municipality can effectively operate the site, including, installation of a weighbridge (with 2 year maintenance plan), and Provision of water and septic tank.	Ga-Nala Sports Field - refurbishment and upgrading of the Kriel rugby and soccer sports fields.

Isibonelo - Thungela			Lebohang sanitation infrastructure - sewer network to improve service delivery to Lebohang residents.	Solid waste management – Construction of a mini-transfer station in Embalenhle or Kinross (priority location to be identified by GMLM).	Maths and science learner incubator programme. Community Scholarship/bursary scheme for University, Technikon & TVET Community skills development and capacity building - Operator machine and portable skills; general security officers NQF 3 Learnership; farming; carpentry; welding).
MMS - Seriti			Khonza-Kahle primary school infrastructure. Construction of flea market - 20 stalls in Mhluzi. Rockdale health centre equipment.	Waste collection municipal support project: Wheelie bin procurement. Municipal waste support project: Waste removal trucks & TLB procurement.	Youth development: Portable skills programmes. Community Bursaries.
Khutala - Seriti	Land provision and monitoring of Fly Ash project.		Municipal road infrastructure support project: Re-gravel 100 km and eradicate 5 km of roads: 2018-2022. Phola community health centre infrastructure.	Waste collection service support – Supply of wheelie bins.	Technical Skills Development Project. Community Skills Development (Bursaries). South32 After Schools Program (Incubation). MSTA (Mathematics, Science, Technology and Accounting) Winter Schools Program.
Kriel - Seriti		SMME support - Capacitating existing and new local businesses and maintaining Information Hub for local SMME's; includes training SMMEs, providing grants and interest free loans to SMMEs that secure contracts with the colliery.	Sewer and water connection infrastructure - Construction of sewer line and construction of water house connection infrastructure in Thubelihle Extension 5.	Emalahleni water infrastructure upgrade – replacement of A/C pipes, bulk water supply, isolation valves and rehabilitation of Point A tower reservoir.	

Table 3.19 Proposed closure plans for mines in the Emalahleni case study area

Colliery	Proposed closure plans		
	Land use	**Infrastructure use**	**Waste**
Khwezela North	A progressive approach to rehabilitation is being undertaken as part of the Green Engine project – potential integrated agri-business, solar PV, waste and water management.	Decommissioning closure plan to be considered alongside integrated project development.	Coal Discard Storage Facilities closure plan: stabilise the deposits so that the site is, depending upon its potential uses, acceptable from the standpoints of environmental impact, aesthetics and safety
Zibulo	Land will be returned to grazing after opencast mining and where feasible arable after underground mining. Wetland rehabilitation plan: Recreation and/or establishment of watercourse through mined out areas.		Discard Dump: At final closure, the discard dump will remain in place, but it will be shaped and revegetated, to grazing final land use capacity.
Greenside	To ensure that the land is restored to that of wilderness or better. Vegetation plan: to create an effective grass cover that will stabilize the soils in the short term and recreate the natural grassland in the long term Wetlands: To rehabilitate affected wetlands to restore some or all of their former function		Integrate rehabilitated dumps into a final land use consistent with wilderness capability.
Goedehoop North	Land capability of the shafts footprint expected to be rehabilitated to arable land by replacing topsoil as recommended by the mine's post closure objectives Other post-mining land expected to be rehabilitated to land capability for a grass mixture		
Isibonelo	Land will be revegetated from 2026 over 3 to 5 years-plans grass mix on rehabilitated open areas; grass mix to consist of quick-covering, matt forming pioneer species and tufted grasses for coverage and long term stability. Pilot study to determine conservation potential started in 2019 following identification high number of mid-sized wildcat species on rehabilitated land around the colliery. Concurrent backfilling being undertaken to fill pits and voids with overburden/interburden. To be levelled and rehabilitated as part of closure plan, and vegetated in line with rehabilitation plan Wetland rehabilitation project – ongoing project to soil and vegetate wetland areas with pasture mix. Phase 1 completed in 2015 included the restoration of two degraded wetlands in the upper Olifants river catchment area.		

3.5 Case study 4: Impact Catalyst – Limpopo platinum

3.5.1 Context

Amplats' Mogalakwena mine began open pit operations in 1993 on the Northern Limb of the Bushveld Igneous Complex, which hosts the world's largest reserves of platinum group metals (PGMs). The mine is about 30 km north-west of the small agricultural town of Mokopane (previously called Potgietersrus) which was founded in 1852 by the Voortrekkers. It is surrounded by rural villages of Sotho kingdoms, which were part of the Lebowa homeland during apartheid, and is situated within the Mogalakwena Local Municipality (established in 2000 as amalgamation of Greater Potgietersrus, Bakenberg and Koedoesrand/Rebone), in the Waterberg District Municipality in Limpopo province (see Figure 3.41). Amplats holds the mineral rights over an area of 7,009 ha in terms of a joint-venture agreement with various partners, and has the right to prospect and mine a further 9,200 ha (Anglo American Platinum, 2017). Mogalakwena Mine is predominantly located on land owned by the Mapela Traditional Authority (TA) and has relocated three villages – Ga-Pila (Sterkwater), Ga-Puka (Rooibokfontein) and Ga-Sekhoalelo (Armoede) which are now semi-urban settlements.

Mogalakwena mine has a life of mine of 76 years, although it has mineral resources and reserves that can extend it significantly. Ore containing the PGMs, copper, nickel and gold, is milled at the on-mine North and South concentrators, and a third concentrator is planned. Concentrate is sent to the Polokwane smelter about 90 km to the east of the mine and concentrator (Figure 3.42). From there, the matte is sent to the Anglo Converter Plant, Base Metals Refinery and Precious Metals Refinery in Rustenburg for further upgrading. Together, the Mogalakwena mine and Polokwane smelter make up the Mogalakwena Mine Complex. Anglo Platinum defines this mine community as all mine workers living in the municipalities of Mogalakwena, Aganang and Polokwane (SLP, 2017), home to over a million people (StatsSA, 2012). The mine has a policy of employing residents from the mine community so the labour sending areas are the local villages and towns. Mogalakwena employs 4,649 employees including 2,825 contractors, and 3,437 of these come from Limpopo province. Only 2.3% are from SADC countries.

Between Mokopane and Mogalakwena mine (see Figure 3.42), the Ivanhoe Mines' Platreef underground mine is in pre-production with shaft sinking reaching 950 m. The mine and concentrator project is expected to reach full production in 2025 with a current life of mine of 30 years but potentially 125 years based on current mineral reserves (Ivanhoe, 2023). Five PGM exploration projects (Sibanye-Stillwater's Akanani project, Platinum Group Metals' Waterberg project, Atlatsa Resources' Rietfontein project, and Sylvania's Volspruit and Aurora projects), one vanadium project (Bushveld Minerals) and one nickel project (Uru Metals' Zebediela project) are underway on the Northern Limb.

Table 3.20 Platinum mines in the Mogalakwena area

Company	Mine	Mining method	Life of mine	Employees
Amplats	Mogalakwena	Open pit	76 years	4,649
Ivanplats	Platreef	Underground	30 years	~100

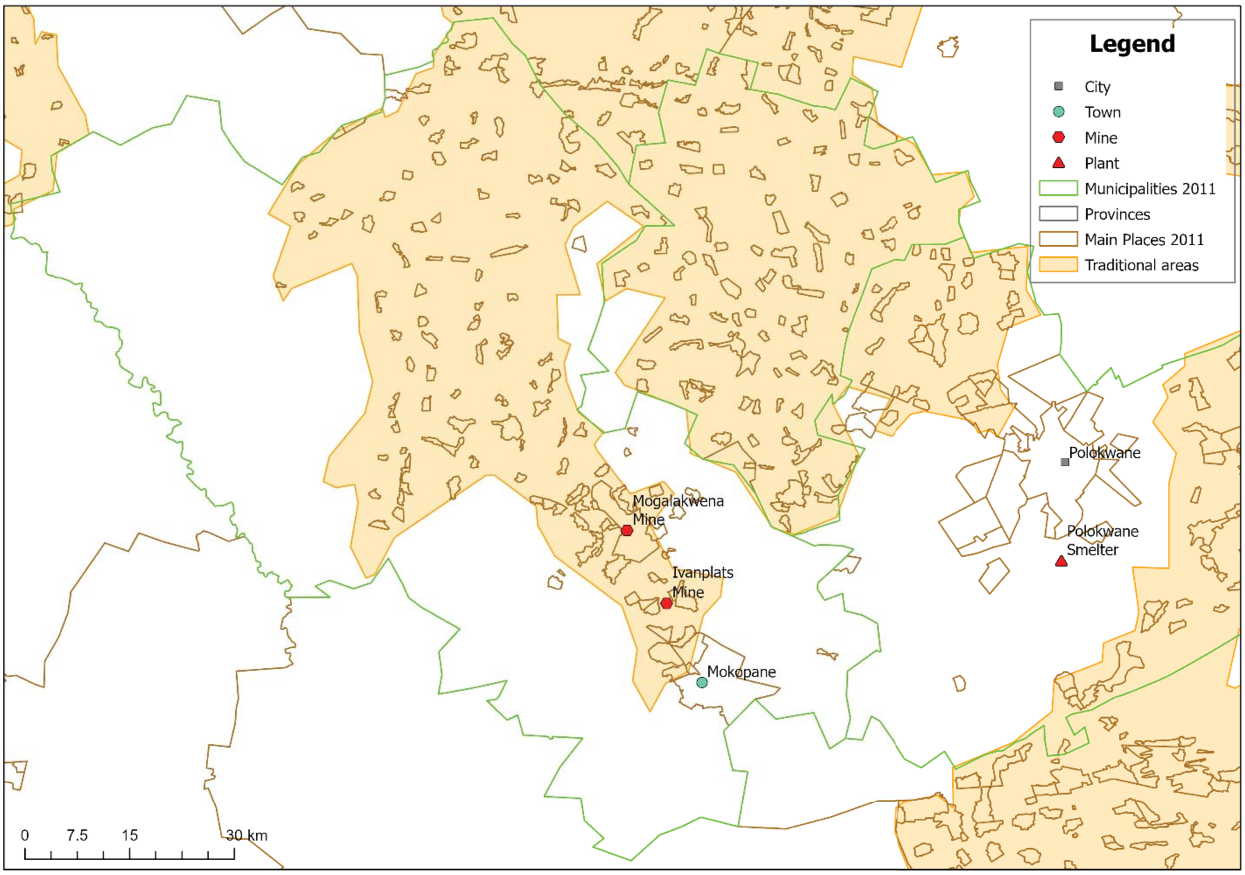


Figure 3.42 Map of mining operations, communities (main places), traditional areas and local municipalities in the Mogalakwena case study (Cole, 2023)

3.5.2 Social vulnerability

According to the 2022 census, the Mogalakwena LM has a total population of 378,198, which has been steadily increasing since 1996 (see Figure 3.43). Almost a third of the population is age 14 or under, and the dependency ratio is 52 (StatsSA, 2023). The Mogalakwena LM is largely rural, but has four clusters of settlement:

1) Mokopane, Mahwelereng township and peri-urban areas in the south,
2) Mapela and surrounding villages near the platinum mines,
3) Bakenberg tribal area in the centre of the LM and north of the mines, and
4) Rebone township and surrounding villages in the far north.

The communities in the area are governed by Traditional Councils and Leaders, with the Mapela and Mokopane Traditional Authority being recognised in terms of the Traditional Leadership and Governance Framework Act, Act 2 of 2005. The villages in the rural areas are closely linked to subsistence farming, with many households depend on agriculture for their livelihoods. Livestock farming is the predominant enterprise within the peri-urban areas, however, there is limited land to carry the current amounts of livestock (SRK, 2021). There are currently four informal settlements – Mzombane, Mountain View and Shushumela at Ga-Pila, and Matebeleng of Chief Ledwaba – and 11 land invasions identified in Ga-Machikiri, Ga-Magongoa, Ga-Puka (Rooibokfontein), Ga-Sekhaolelo (Armoed), Mapela next to Skimming, and Bakenberg. These are all within 10 km of Mogalakwena mine or Ivanplats mine (Figure 3.44).

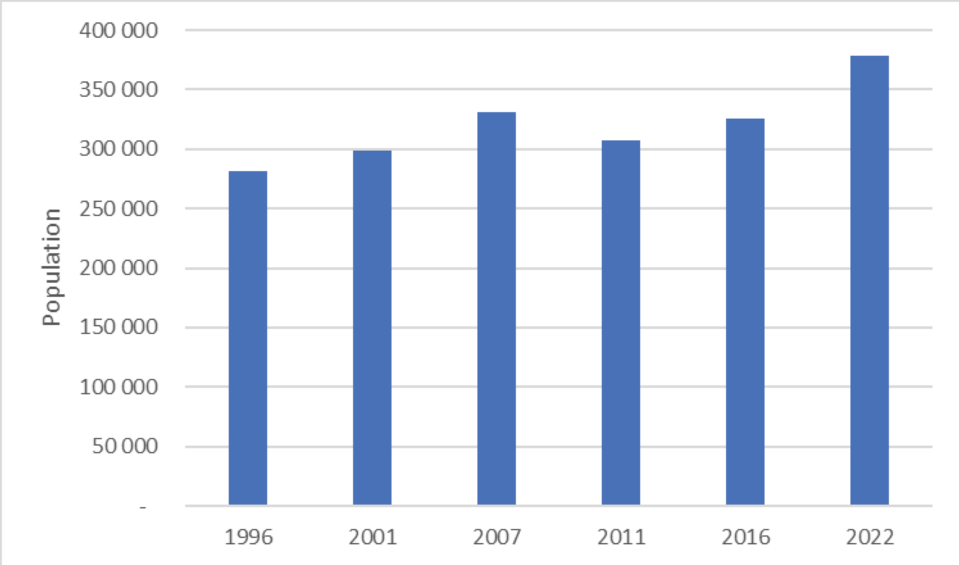


Figure 3.43 Population growth in Mogalakwena Local Municipality (source data: StatsSA)

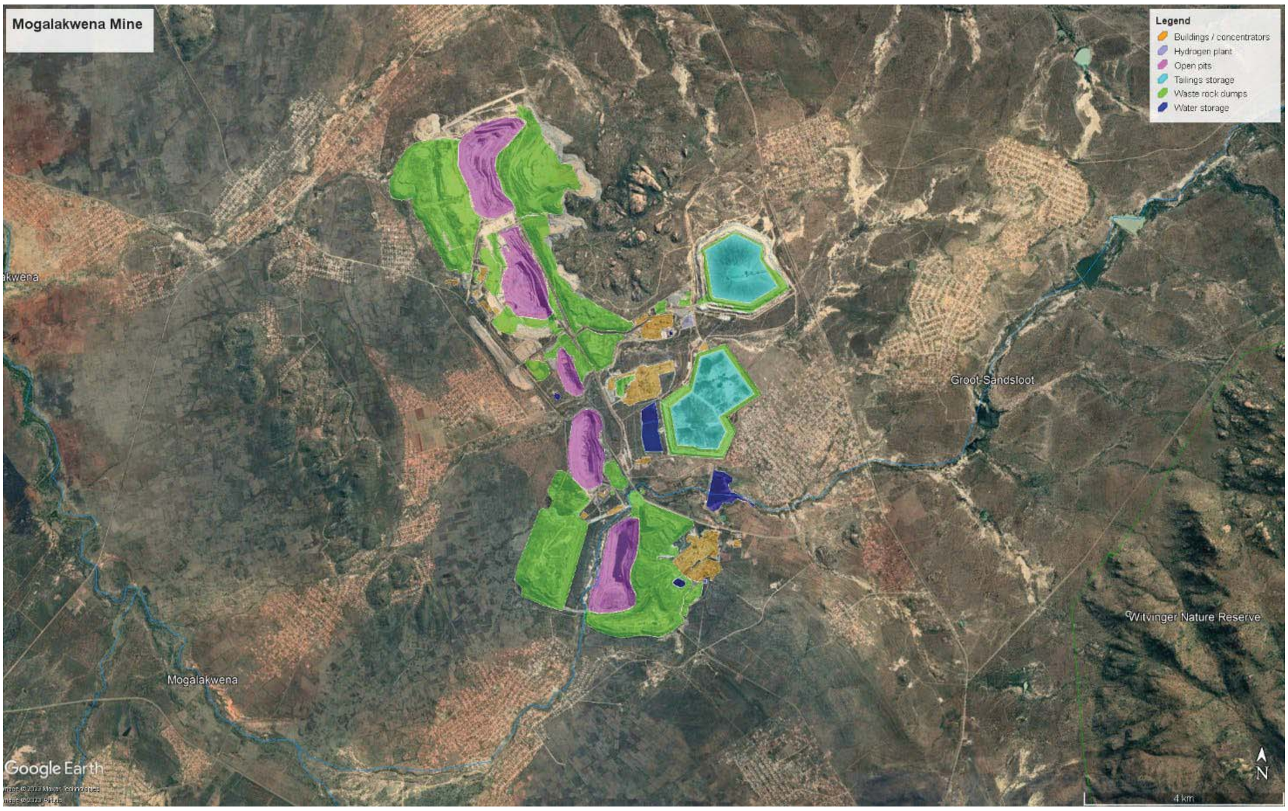


Figure 3.44 Satellite map of Mogalakwena mine are showing site features and doorstep communities (Cole, 2023)

The case study focuses on the Mokopane and Mapela area within Mogalakwena LM where the current Mogalakwena mine operates and three other large-scale mines are in development. The demographics and socio-economic indicators for these communities are given in Table 3.21 and Table 3.22 and Figure 3.45. They show a trend of declining well-being from the town to the townships then peri urban areas and finally rural villages. The stark contrast between the villages around the mines and the towns where much of the mine workforce live, partly explains why there have been so many conflicts between the mine and the community.

Table 3.21 Summary of communities in the Mogalakwena case study

Types of community	Number of communities	Population in 2011		Male (%)	Race (% non-white)
		people	%		
Town (Mokopane)	1	30,151	15.6	49.2	63.0
Townships (Mahwelereng)	6	90,451	21.2	46.7	99.9
Peri-urban	6	30,308	15.7	47.1	100
Mapela villages	20	42,440	21.9	45.7	100
Informal settlements (Mountain View)	1	191	0.1	49.2	100
TOTAL	34	193,541	100		

Table 3.22 Socio-economic indicators for the Mogalakwena area

SDG	Indicator	Mogalakwena LM	Mokopane	Townships	Peri urban	Mapela villages
1	Household income (% above R19,600/year)	45.8	74.8	73.3	64.8	55.2
	Household goods (% fridge ownership)	75.1	72.6	78.2	78.2	64.8
3	Health (% with disability)	68.7	73.1	70.2	70.8	55.7
4	Education (% with Grade 12 or above)	30.5	56.5	35.2	23.6	19.6
6	Water access (% piped water in home or yard)	62.5	87.9	72.1	43.1	34.4
	Sanitation (% access to toilet)	28.7	97.9	46.1	41.9	8.7
7	Electricity access (%)	93.1	79.3	98.2	97.9	79.9
	Clean cooking fuel (%)	57.0	80.3	85.2	59.9	51.6
8	Employment (% labour force)	53.0	75.1	56.6	38.8	36.0
11	Formal housing (%)	94.5	99.2	96.1	93.4	79.5
	Refuse removal (% municipal)	26.6	78.8	36.2	0.7	9.1
17	Internet access (%)	22.5	47.2	25.6	18.3	15.8
	Overall well-being score	5.6	7.8	6.4	5.3	4.3

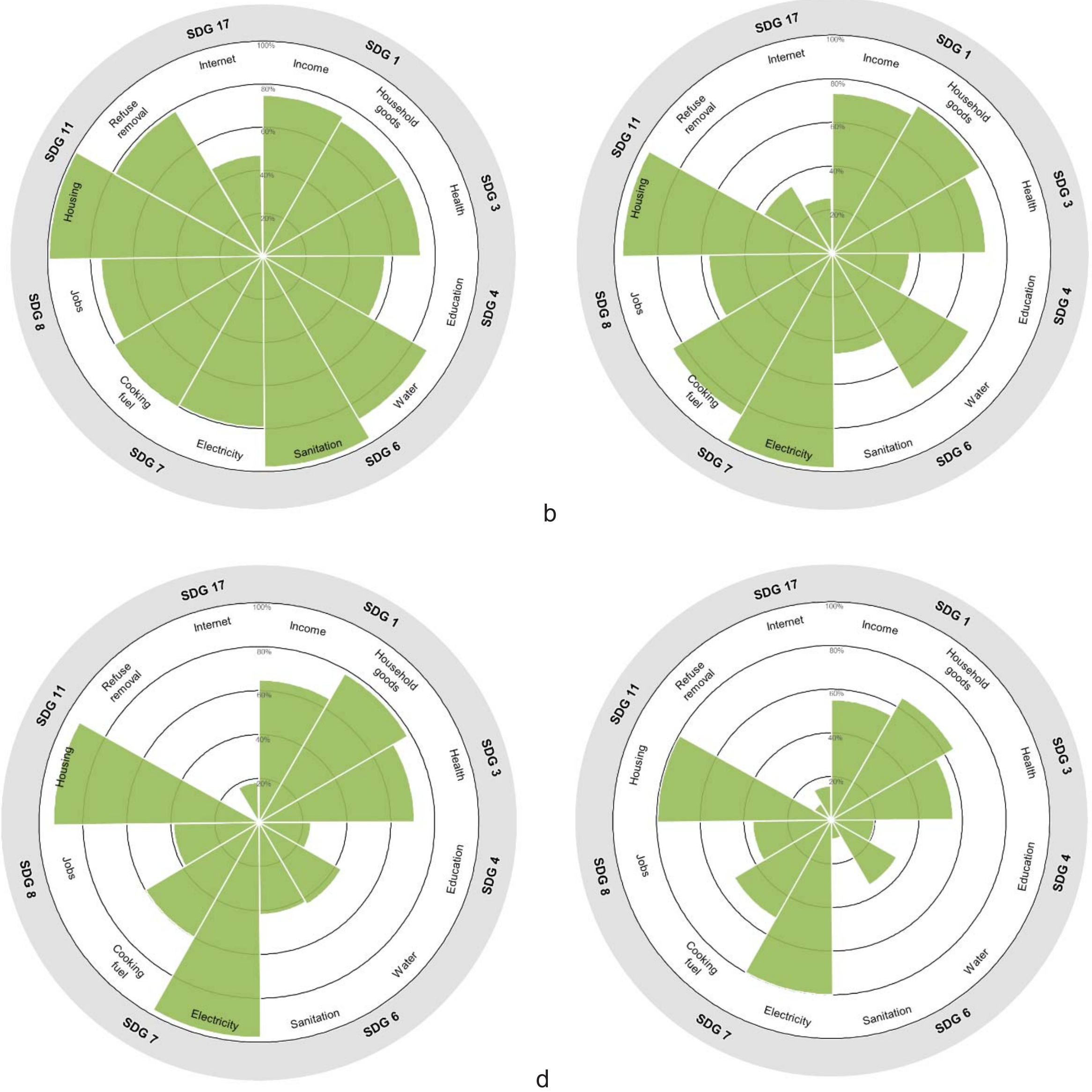


Figure 3.45 SDG barometers for a) Mokopane town, b) townships, c) peri urban villages, and d) Mapela villages in the Mogalakwena case study area (Cole, 2023)

The Mogalakwena LM received a negative audit outcome of the past three financial years (IDP 2021/22) and is one of nine municipalities that are part of the Anglo American Municipal Capacity Development Programme, developed through a memorandum of agreement with the Department of Cooperative Governance and Traditional Affairs, with the Council for Scientific and Industrial Research (CSIR) as the implementing agent. The programme was developed in recognition of the specific challenges facing mining municipalities and especially mining regions under transition. The programme's emphasis is on institutional, organisational and individual capacity, in line with government's capacity development framework, and aims to complement existing service delivery functions within local municipalities.

3.5.3 Environmental impacts and risks

Land

The land capability in the Mogalakwena area has a high proportion of moderate arable land and large areas of wilderness land (Figure 3.46). The soils are classified as sandy and shallow, with high clay content. The soils along the rivers have the highest agricultural production potential and were therefore the areas impacted on in the past by various agricultural and human activities (Mogalakwena Local Municipality, 2021). The area around the mine has moderate-to-high grazing potential, making it suitable for livestock. Current land use in the Mogalakwena municipality is largely commercial farming and subsistence agricultural land, with some areas are allocated to urban settlements, mining and industrial activities (Mogalakwena Local Municipality, 2021), as shown in Figure 3.47. The municipality owns substantial amount of land for both residential and industrial development, however it does not have any control of land under the rural areas as the land belongs to the tribal authorities. An estimated 252,342 ha of land is currently under land claims, while the remaining is distributed between communal ownership, individual ownership and municipal ownership. The Municipally currently faces challenges of Illegal occupation of land and growing informal settlements in both urban and rural areas (Mogalakwena Local Municipality, 2021).

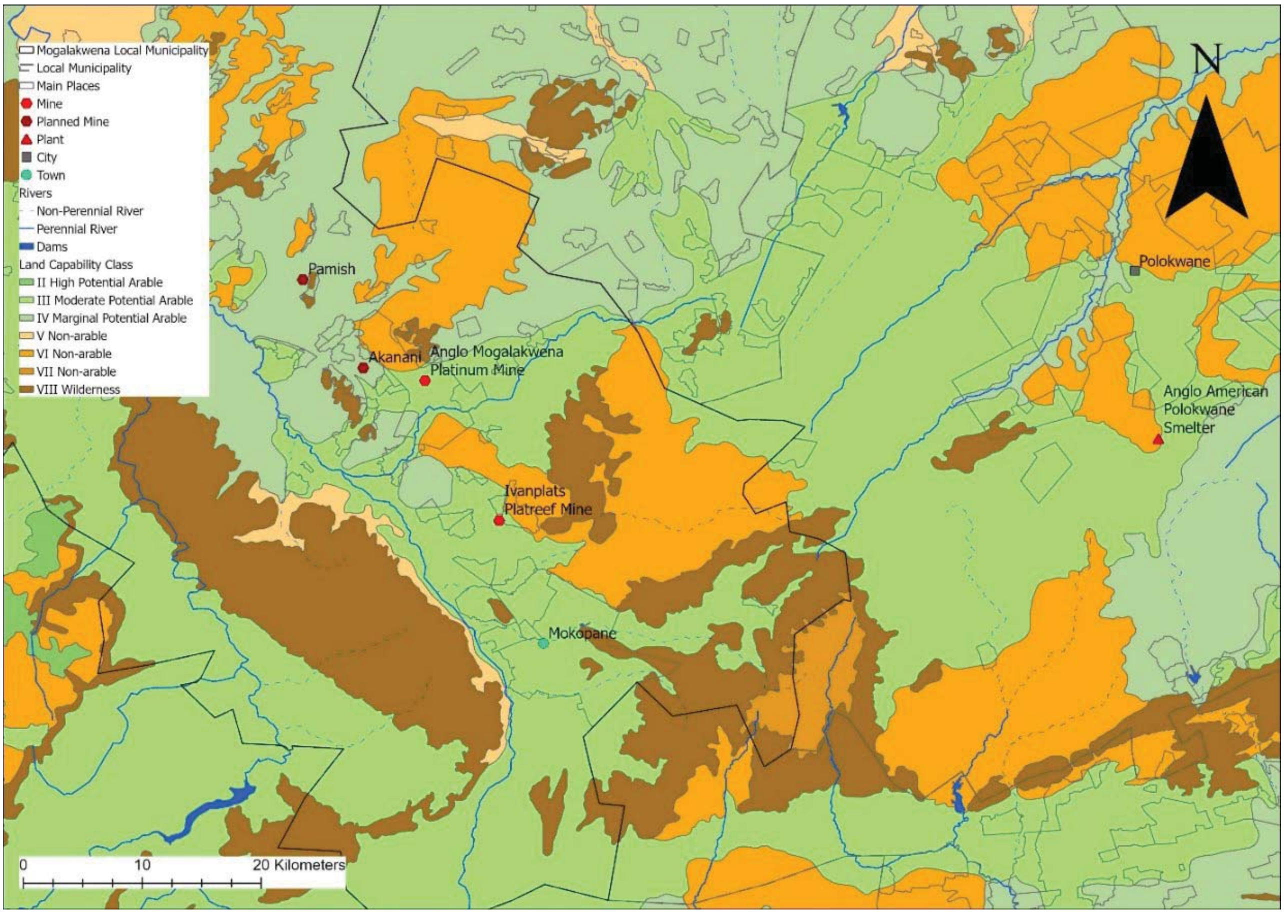


Figure 3.46 Land capability for the Mogalakwena area

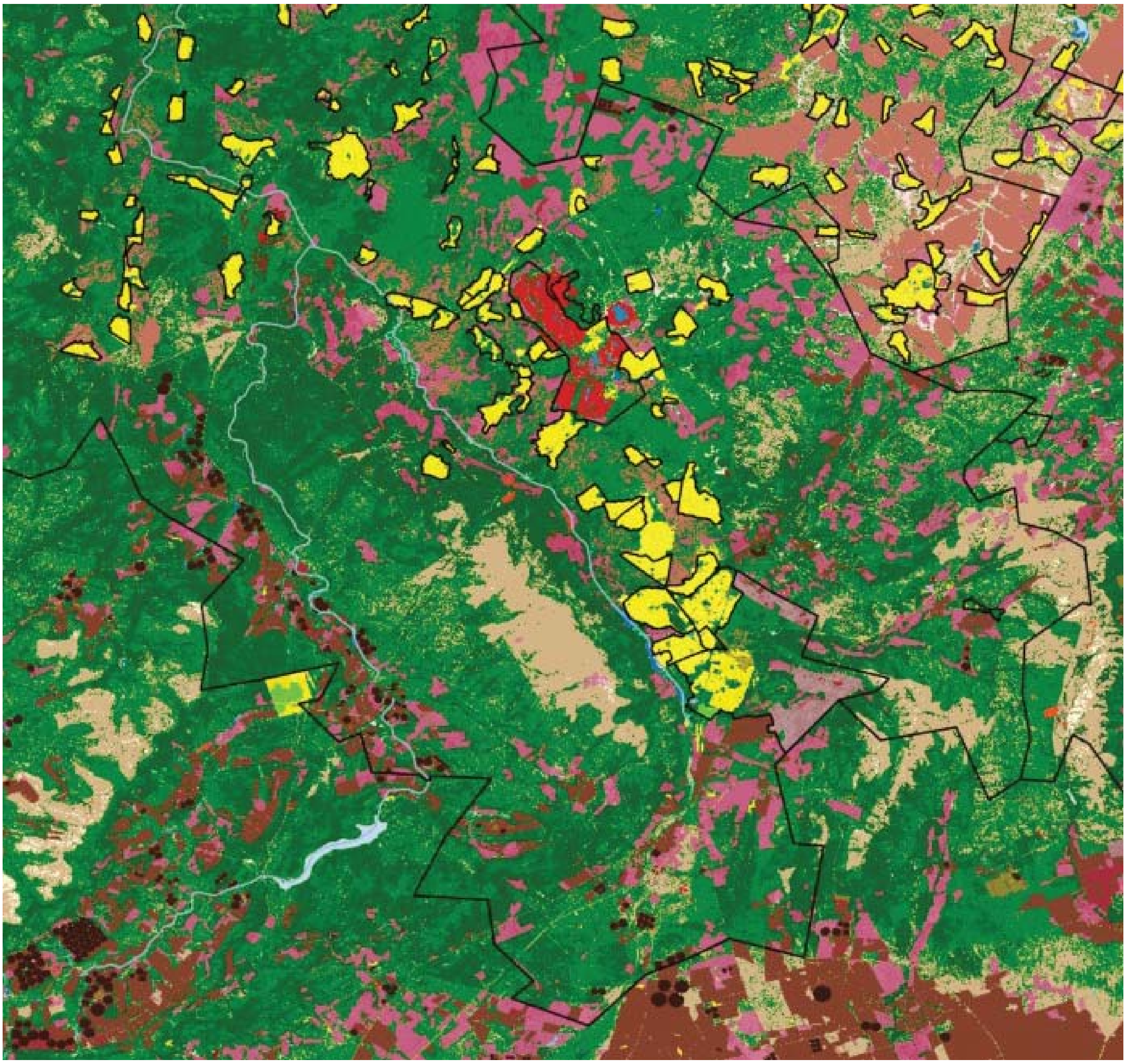


Figure 3.47 Land cover in the Mogalakwena area showing mining (red), residential areas (yellow), agriculture (purple and brown) and forests and woodlands (green) and community boundaries (in 2011)

Water

The Mogalakwena area is a summer rainfall region, with average rainfall between 600 mm and 650 mm, and a hot semi-arid climate. The Sterkrivier flows alongside the western border and flows into the Doorndraai Dam (Figure 3.48). The Mogalakwena River Catchment covers an area of 19,327 km² and the MAR is around 140 m^3/a. The Mogalakwena River has two tributaries, the non-perennial river Pholotsi River which flows past the Ga-Mapela and Pholotsi villages, and the Thwathwe River which flows past the Ga-Mabuela and Ga-Masoge villages. The most prominent features in the catchment are the Nylsvlei floodplain, Mamatlakala wetland, Glen Alpine Dam, which supplies the immediate and downstream area with water for both primary use and irrigation. Mogalakwena LM is a Water Service Authority (WSA) and also a Water Service Provider (WSP) and experiences water demand of 68.6 Ml/day (31.9 Ml/day for urban areas, 8.3 ML/day for peri-urban areas, 26.3 ML/day for rural areas and 2 ML/day for mines) and water losses of 40.5%. Mogalakwena townships and villages are largely dependent on boreholes for water supply, mostly installed along the riverbanks. Water quality is a problem, due to lack of water infrastructure (there is only one wastewater treatment works in Mokopane) and refuse removal, and industrial effluents, and outbreaks of waterborne diseases are common.

Mogalakwena mine receives potable from the Commandodrift (1-1.4 Mℓ/day), PPL (2 Mℓ/day) and Blinkwater (1.8 Mℓ/day) wellfields under the mine's water use licence. Most of the wellfield water is used for domestic purposes and only a small percentage is used in the process at Mogalakwena South Concentrator. Process water is obtained from recycled sewage effluent from the on-site sewage treatment plants, the Mokopane WWTW (authorised up to 6 Mℓ/d) and Polokwane (authorised up to 20 Mℓ/d) WWTW, as well as pit dewatering and return water from the TSFs. Both concentrators make extensive use of recycled water, which has been collected and stored on the mine premises (SRK, 2021).

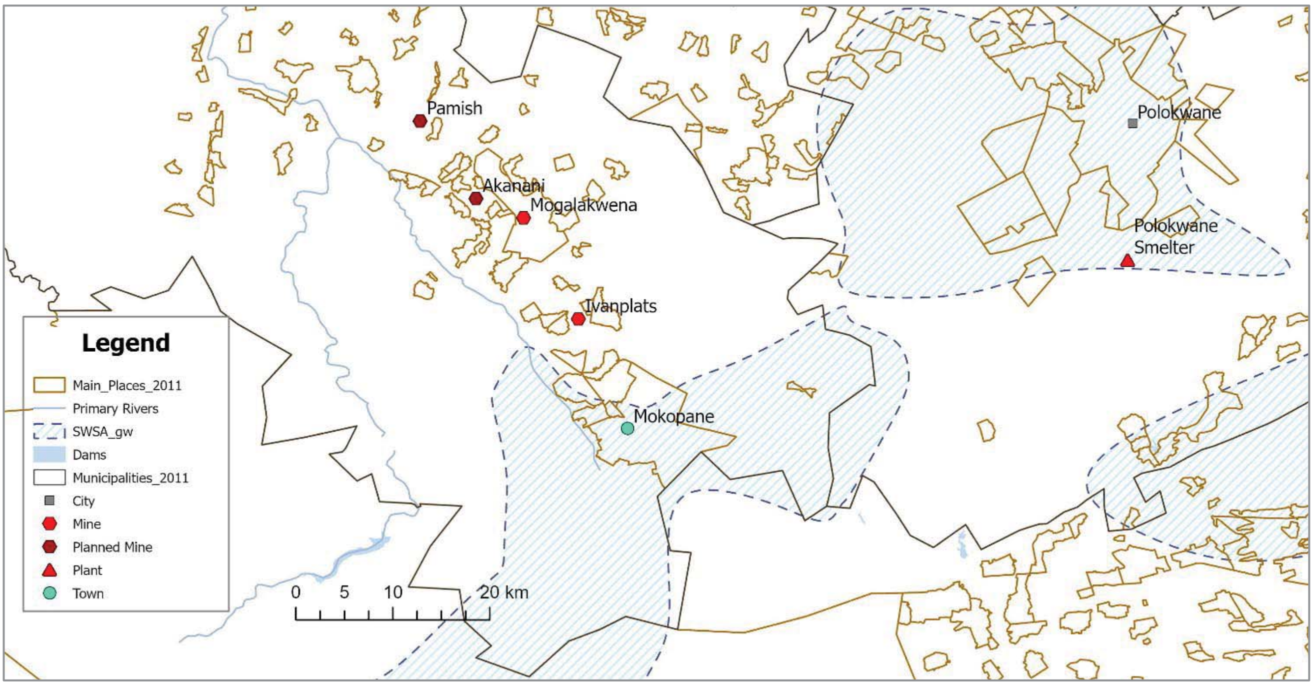


Figure 3.48 Strategic water resource areas, dams and rivers in the Mogalakwena case study area

Water scarcity is a major concern in Mogalakwena LM, and the Limpopo province experiences severe droughts and has few reliable water sources. Demand increased by 52% from 2015 to 2020 and is expected to continue to rise with the increase in mining activities and the continuous growth of local communities, putting additional strain on water supply (Mogalakwena Local Municipality, 2020). The Mogalakwena LM has laid infrastructure for the functional water scheme to accommodate the envisaged bulk water supply from Flag Boshielo Dam to supply various communities as well as for the anticipated mining developments within the area (Mogalakwena Local Municipality, 2021). As part of the Water Master Plan the municipality is also in the process of negotiating additional bulk water with relevant role-players to augment the current water with basic water supply to 130 villages expected by 2025 (Mogalakwena Local Municipality, 2021). As part of Mogalakwena mine's SLP, Amplats is undertaking a project to supply water to 35,000 people in the Mapela Community (22 villages). Similarly, Ivanplats has committed to provide local, treated bulk water from Mokopane's new Masodi treatment plant for the first phase of production at Platreef, with a minimum of 5 Ml/day for 32 years beginning in 2022. Ivanplats will provide financial assistance to the municipality for certified costs of up to a maximum of R248 million (approximately US$19.6 million) to complete the Masodi treatment plant and purchase the treated wastewater at a reduced rate of R5 per thousand litres for the first 10 Ml/day to offset a portion of the initial capital contributed.

Biodiversity

Mogalakwena LM is situated in the Waterberg Biosphere, the first "savannah" biosphere reserve registered in Southern Africa and one of the biggest conservation areas in the country with a large population of big game, important prehistoric and historic sites and large areas of unspoilt bushveld. It has five nature reserves scattered throughout the area used for outdoor recreation and breeding of wildlife, namely: Wonderkop, Masibe, Moepel, Witvinger and Percy Fyfe, and one World heritage site Makapansgat (Figure 3.49). These nature reserves contain seven veld types: Arid Sweet Bushveld, Mixed Bushveld, Sourish Mixed Bushveld, Sourish Bushveld, Pietersburg Plateau False Grassveld, Springbok Flats Turf Thornveld, North Eastern Mountain Sourveld. The veld types contain unique plant communities and/or plant species and some of these are endemic such as the *Encephalartos eugene-maraisii* (Mogalakwena Local Municipality, 2021). The areas where special vegetation communities mostly occur are in the mountain ranges and along drainage lines. The riparian vegetation along the banks of the perennial rivers and streams are an area of high sensitivity. There are Critical Biodiversity Areas in Bakenberg Mountains and other areas that contain species of concern (ibid).

The location of the reserves provides an even spread of facilities to be used for future environmental and conservation initiatives and presents an opportunity to form corridor zones between core zones, as well as linking up with identified community land as part of conservancies (ibid). The Waterberg Biosphere Reserve received its international status in March 2001 and now forms part of the World Network of biosphere reserves, registered with the United Nations Educational, Scientific and Cultural Organization (UNESCO). The Makapan World Heritage Site has been a site for paleo- anthropological discoveries as well as the conflict between Boer and Pedi in 1854. Mogalakwena LM is affected by soil erosion especially at the communal areas, exacerbated by deforestation for firewood and traditional herbs, overgrazing, some agricultural cultivation practices, the removal of vegetative cover or hedgerows, and uncontrolled veldt fires. Despite having electricity, most rural households continue to use firewood to reduce their electricity costs and to earn income.

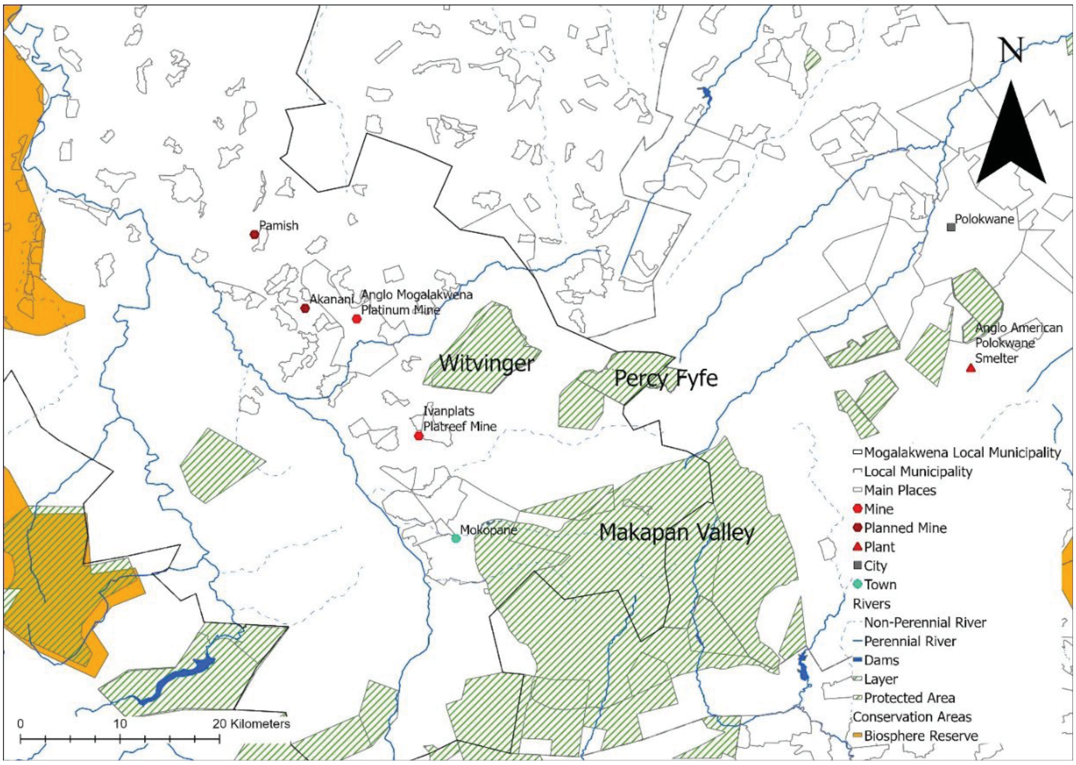


Figure 3.49 Protected areas and reserves in the Mogalakwena area

Air pollution

A total of 32 dust fallout sampling stations have been installed in and around the Mogalakwena Mine project area, 18 Residential Area and 14 Non-residential Area dust fallout units. Three PM_{10} sampling stations have been installed within the Mogalakwena project area. All monitoring points are compliant with the National Dust

Control Regulations and below air quality thresholds (SRK, 2021). Dispersion modelling of PM_{10} showed the maximum predicted concentration occurs within the mine boundary and decreases with distance away from the mine. The pollutant plume moves towards the southwest and west of the mine. The predicted 24-hour concentrations at the sensitive receptors are below the South African NAAQS of 75 µg/m^3 and below annual NAAQS of 40 µg/m^3. Similarly, the predicted 24-hour and annual PM2.5 concentrations at the sensitive receptors are below the South African NAAQS of go 40 µg/m^3 and 20 µg/m^3 respectively. The dust fallout modelling at the sensitive receptors are below the Residential Area standard of 600 mg/m^2/day, with the highest concentration occurring within the mine boundary. The plume is predicted to be concentrated over the main operational activities such as the crushing activities at the concentrator, TSF and Water Return Dam. Very low concentrations at the sensitive receptors are predicted beyond the boundary of the mine (SRK, 2021).

Waste

Mogalakwena mine has eight waste rock dumps, with a total footprint of 2,182 ha and a maximum height of 60 m. It operates three tailings storage facilities (TSF) located within the mine area, namely Vaalkop TSF (built in 1992), Vaalkop extension TSF (built in 2004) and Blinkwater TSF (built in 2011). Tailings from the Mogalakwena North Concentrator are pumped via an existing pipeline to the Blinkwater TSF whilst the Vaalkop TSF Complex receives tailings from the Mogalakwena South Concentrator.

3.5.4 Land use opportunities

Impact Catalyst project

In this case study we focus on the Impact Catalyst initiatives at Amplats' Mogalakwena mine to understand the challenges and opportunities around the development and implementation of post-mining initiatives where mines still have a significant life of mine. The Impact Catalyst imitative forms part of Amplats' Collaborative Regional Development (CRD) programme, launched in 2016 to create long-term economic development in Limpopo to support communities through partnerships (Anglo Platinum, 2019). The CRD was initially established to address community development around its operations in Limpopo, Mogalakwena and Modikwa mines, which still have significant life of mine. However in 2019, Anglo American along with Exxaro, the Council for Scientific and Industrial Research (CSIR) and the World Vision International officially formed a partnership with the government of Limpopo to drive post-mining economic development through the Impact Catalyst initiative (Anglo American, 2019b). The Limpopo socio-economic development platform was launched in 2019 for multiple stakeholders to partner in identifying and supporting opportunities to generate socio-economic and environmental benefits in the province. This work has included biodiversity offset and agricultural initiatives that optimise the use of available (non-operational) land at a regional scale in these sectors (Anglo American Platinum, 2020). The initiative aims to identify socio-economic development opportunities through spatial planning and support partnerships with a broad range of stakeholders including community representatives, faith groups, businesses and entrepreneurs, government, academics and NGOs. Impact Catalyst subsequently launched similar platforms in the Northern Cape and Mpumalanga provinces. The Impact Catalyst focuses on six areas of impact (Table 3.23) to establish inclusive, collaborative, cross-sectoral platforms, initiatives and partnerships to achieve systemic socio-economic impact.

The current Impact Catalyst Projects related to land use are:

- Mooihoek Integrated Game Farm is being developed as co-development initiative aimed at exploring the identification of game farming and alternative agricultural value chain opportunities, including the potential of a commercial joint-venture with the neighbouring Mogalakwena owned Groenfontein Farm. The Mooihoek Farm is currently managed as a game ranch for recreational hunting, however, the land is in the process of being transferred to the Armoede community, who through the Armoede Community Development Trust, will be the ultimate beneficiaries of the initiative.

- Agro-processing and biodiesel production facility. Amplats and the CSIR are working together to investigate alternative livelihoods for communities around the Anglo Mogalakwena mine.
- Mutale Agri Industry Development: This project is looking at repurposing the Unwa Dam (built by Exxaro for their now-closed Tshikondeni mine) to provide irrigation to an area in the community where possible agricultural activities can be developed.
- Mpumalanga Winter Wheat Pilot is an agricultural programme that aims to determine whether remediated mine land and mine affected water, offer sustainable livelihood opportunities for the community surrounding a closed mine.

Table 3.23 Impact Catalyst focus areas in 2021

Focus Area	Objective
Economic development	Aims for simple, low-income national economies to be transformed into modern, industrial economies.
Environment	Conserving natural resources and developing alternate sources of power while reducing pollution and harm in the environment. Building a robust biodiversity economy that contributes substantially to the financial and economic climate in South Africa.
Social empowerment	Support social development. Acting individually and collectively to change social relationships and the institutions and discourses that exclude poor people and keep them in poverty
Education	Improve access to formal, informal and non-formal education and attainment thereof.
Health	Increase control over, and to improve health of communities through a wide range of social and environmental interventions.
Service delivery	Enhance governance processes, skills and capacity through support interventions to municipal and provincial governments, to improve delivery performance of municipal and provincial services.

The initiative's approach to creating a platform for the formation of partnerships around various post-mining land-uses and SMMEs gives insight on how various stakeholders can collaborate and engage to support regional development beyond mining. Amplats benefits through collaboration on socio-economic development, delivery of programmes, value for-money through co-funding and stimulation of other regional economic pillars to reduce dependency on the mines (Anglo American Platinum, 2019). Several feasibility studies and pilot programmes are currently underway in Limpopo, spanning across integrated game farming, agriculture, agro-processing and biofuels, waste recycling and community health (see Figure 3.50). There are several other projects currently in the pipeline that have also been integrated into Amplats' SLPs.

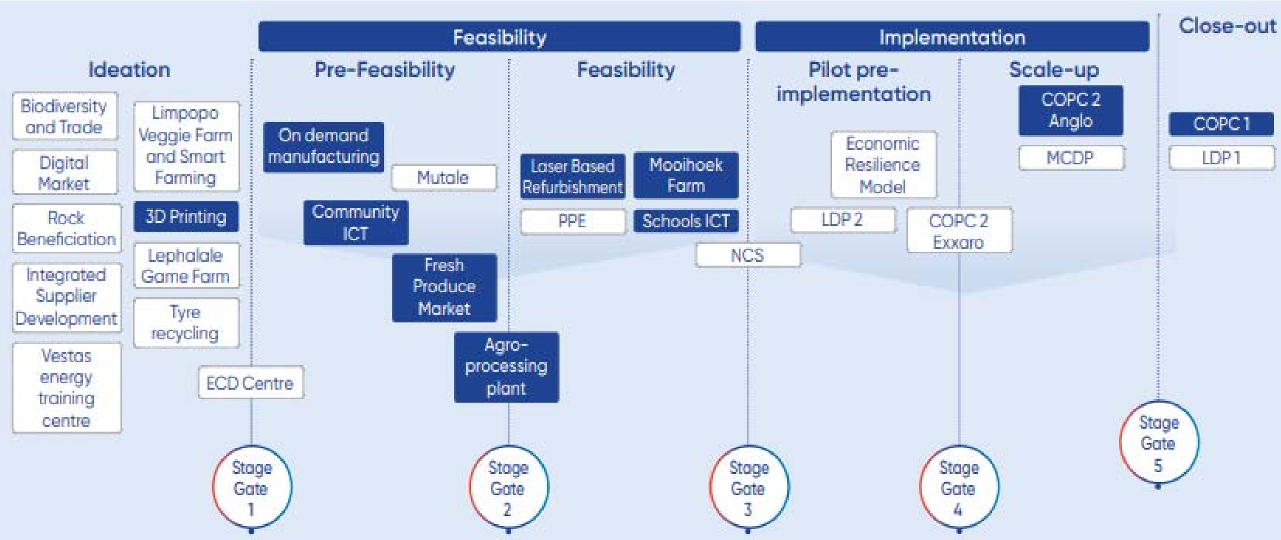


Figure 3.50 Impact Catalyst pipeline of projects with Amplats initiatives shown in blue (Anglo American Platinum, 2021)

Project development across the Impact Catalyst was however delayed in 2020 due to Covid-19 effects which affected interactions with key stakeholders and project planning and implementation (Anglo American Platinum, 2021). Projects that have advanced into implementation phase include the Community-oriented Primary Care project which provides health support to rural communities, and some relief to overburdened health clinics. Since its pilot phase at Mogalakwena in 2019, this project has been scaled across all Anglo-American Platinum operations in South Africa and adopted by Exxaro in its mining areas (ibid). ICT has been identified as a key area as Mogalakwena mine is surrounded by rural communities and projects under consideration include community-wide and schools-focused projects (Anglo American Platinum, 2019). Key projects identified to integrate land management, water management and development initiatives include agriculture and agro-processing, which are largely still in the feasibility stage.

Mooihoek Integrated Game Farm

The Mooihoek Integrated Game Farm is a co-development initiative exploring game farming and alternative agricultural value chain opportunities, including a potential commercial joint-venture with the Mogalakwena mine-owned Groenfontein Farm. Amplats is managing Mooihoek and Groenfontein as an integrated conservation area, with some game ranch activity at Mooihoek (Figure 3.51) for recreational hunting (Anglo American Platinum, 2020). Surveys are underway to determine the conservation potential, biodiversity and species in the area (ibid), so far identifying 10 species of small mammals (mice, shrews, gerbils, etc.), nine bat species and 165 bird species (Anglo American Platinum, 2019). Heritage sites of significance have also been identified in the nearby Mohtlotlo hills and these have been declared an exclusion zone and biodiversity protection measures, approved by authorities and local communities, will be implemented (Anglo American Platinum, 2020). Some legacy resettlement issues with the affected community are also expected to be resolved as part of the implementation of the Mooihoek project. The title deed of the Mooihoek farm was transferred to Armoede Community Development Trust in October 2021 as part of a resettlement agreement and a joint-venture agreement for the continued development and management of the property has been established (Anglo American Platinum, 2022).

Figure 3.51 Mooihoek integrated game farm establishment (Impact Catalyst, 2021)

Assessments for the capacity for the business model and the expanded value chain are also being developed. Value chain analysis (Figure 3.52) is being conducted to assess the development of a commercial game ranch and the beneficiation of the game animal value chain for the hunting and sale of game meat, breeding, live sale, taxidermy of trophies and leather manufacturing, tourism, and recreational activities (Newman, 2018, Impact Catalyst 2021). To support community capacity building for the development of game farming land use, Mogalakwena Mine has an incubator support programme on its Groenfontein farm designed to promote the community cooperatives and SMMEs across the value chain (Anglo American Platinum, 2020).

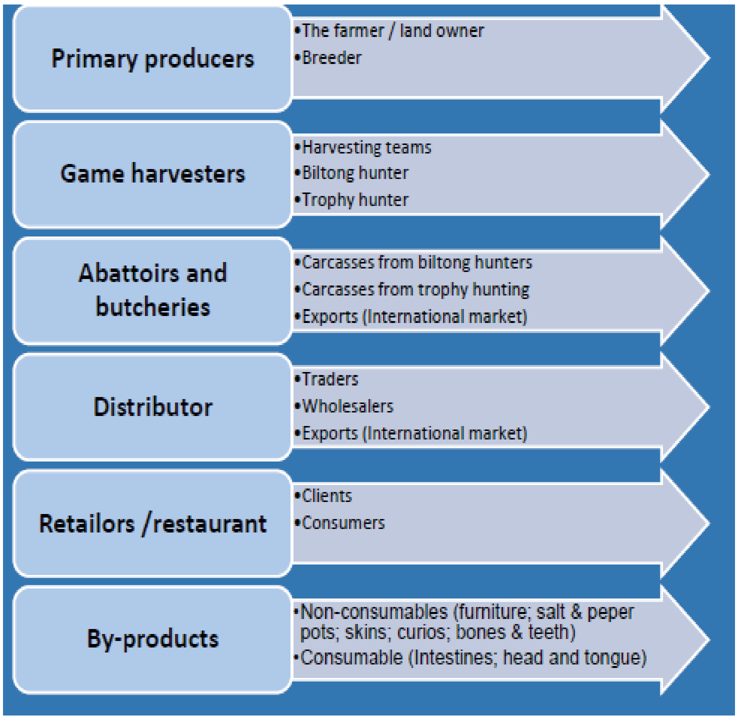


Figure 3.52 Mooihoek integrated game farm value chain analysis (Newman, 2018)

Agro-processing and biodiesel production

Amplats and the CSIR are working together to investigate alternative livelihoods for communities around the Mogalakwena mine through agro-processing and biodiesel production. There are various agricultural activities in the Mogalakwena area which include farming of cattle, poultry, game and citrus. This initiative aims to undertake technical feasibility assessments comprising pre-feasibility of primary production, feasibility of agro-processing, climate proof technology interventions and supply chain analysis, to conduct a basic facility engineering design of the agro-processing and biodiesel facility, and to assess the social impact and market feasibility. The focus is on the primary production of selected crops for value addition through agro-processing and the production of biodiesel. The biodiesel would then be used to run some machinery at the Mogalakwena mine with any excess sold to other users.

A study in 2019 showed that the viability of the proposed agro-processing and biodiesel production facility will partly depend on its ability to source its raw material inputs from local agricultural production (Habiyaremye et al., 2019). The area has considerable land resources, but local agricultural production continues to be constrained by water scarcity and lack of irrigation infrastructure. The study also shows that the provision of appropriate irrigation infrastructure can be achieved through collaboration with the national Department of Water Affairs and Sanitation and Mogalakwena LM integrated development planning, which are already working on increasing the capacity of the water supply system for local communities (ibid).

Identifying the supply chains is an important factor for the agro-processing and biodiesel production, participating farmers, cooperatives or other entities to source inputs (such as seeds, seedlings, agricultural implements, machinery, fertilisers, etc.) as well as ancillary activities for harvesting transport and storage (Habiyaremye et al., 2019). Currently two private companies are the major players in the agricultural supply chain of Limpopo province and render various services to farmers for their agricultural needs such as farming equipment and supplies, including irrigation systems, tractors, seedlings, fertilisers, and pesticides (ibid). In addition to the bigger players, there are several minor suppliers, each one specialised in specific branches of the value chain, such as supplying seeds, seedlings, agricultural chemicals, or mechanical implements. Habiyaremye et al.'s (2019) findings also show that there are sizeable local markets for agricultural products in the area.

Other land use opportunities in the study area

Solar power

The Mogalakwena LM has a high solar irradiation potential which presents an opportunity for solar power to meet increasing demand and improve access to electricity. There are currently four solar power projects in the Waterberg District (ENGIE, 2021) – Soutpan Solarpark (28 MW capacity), Tom Burke Solar Park (60 MW), Witkop Solar Park (30 MW) and Bella Mall (1 MW). The area around the Mogalakwena Mine received between 1,972 kWh/m^2 and 2,018 kWh/m^2 annual solar radiation in the period from 1994 to 2018, which is on the higher end of the South African average (Zutari, 2020). Amplats is building a 100 MW solar PV plant operated by Pele Green Energy, which may be expanded in future. Amplats will have 10% free carry in project, with the resulting dividends attributable directly to host communities over time. The plant is expected to power the mine and excess power will be used for green hydrogen production (Anglo American Platinum, 2021).

Hydrogen hub development

The development of the hydrogen economy has potential for South Africa to transition to a low-carbon economy, and an opportunity to grow downstream PGM beneficiation capacity as PGM catalysts are used in hydrogen value chains (DSI, 2021). The Hydrogen Roadmap for South Africa, released in October 2021, identified three possible hydrogen hubs – Johannesburg, extending to Rustenburg and Pretoria; Durban, encompassing the city and Richards Bay; and Limpopo province centred around Mogalakwena PGM mine – with a fundamental role in integrating hydrogen into South Africa’s Platinum Valley Initiative (DSI, 2021; Anglo American Platinum, 2022). Key pilot projects in transport, industrial and construction have been identified across these hubs and recommended to developers. The Mogalakwena-Limpopo hub has been identified for the establishment of hydrogen fuel production and hydrogen-powered medium-to-heavy vehicles such as hydrogen fuel-cell powered buses, forklifts, and heavy-duty and mining trucks (ENGIE, 2021). Amplats installed a 3.5 MW capacity solar-powered electrolyser plant at its Mogalakwena mine in 2021 and launched the first hydrogen-powered fuel cell mine haul truck in 2022 (Figure 3.53) and is expected to produce 1 tonne of hydrogen per day to power fuel cell-powered trucks (ENGIE, 2021; DSI, 2021; Anglo American Platinum, 2022). Although the focus for the Mogalakwena hub is on hydrogen production and heavy-moving vehicle supply chain, there is potential to utilise the hydrogen for other industries and create jobs around the production and trucking of hydrogen (ENGIE, 2021). However, the skills gap in hydrogen technology in the country is a potential barrier to the development of the hydrogen economy (DSI, 2021).

a 

b 

Figure 3.53 Electrolyser plant and hydrogen truck at Mogalakwena (Anglo American Platinum, 2022)

Tourism

Mogalakwena has a rich history and cultural heritage resources, which have potential for tourism. Makapan World Heritage Site has been a site for paleo- anthropological discoveries as well as the conflict between Boer and Pedi in 1854. However, the municipality has not yet undertaken a comprehensive heritage survey of the entire municipal area and the heritage information on record is very limited. Other potential heritage sites include; Moordrift Monument, Nyl crossing, Bokpoort pass and Eugene Marais, View of Hanglip, Pedi Potters, Viewpoint to Nagwag farm and the Herero People, Elandskuiling Pass, Telekishi, Masebe Nature Reserve, San bushmen, Magagamatala, Thutlwane Hill, Anna trees and David Livingstone and Plaque for Beyers.

Local economic development

The Mogalakwena LM is mostly rural characterized by inadequate infrastructure and poor levels of service delivery therefore the Mogalakwena mine SLP LED projects are targeted at service provision and infrastructure. As Table 3.23 shows, these activities typically involve infrastructure, education and health facilities; developing local procurement and local suppliers; development; building local capacity; and investing in enterprise and skills development. Enterprise development is supported through various initiatives across the Impact Catalyst project development pipeline and the Zimele Enterprise Development programme. The Ivanplats SLP for 2021 to 2025 focuses on the three infrastructure projects: 1) the provision of equipped municipal boreholes in the villages of Magongoa (Phase 1), Sekgoboko, Kgobudi, Malepetleke, Mokaba, Tshamanhansi (Phase 2) and Mzombane (Phase 3) at a cost of R5 million, 2) the construction of the Tshamahansi Clinic in collaboration with Anglo American (R25 million each) to serve six villages, and 3) construction of Masodi wastewater treatment works with a budget of R72 million. The municipality is expected to take over maintenance of the boreholes once the installation work is completed.

The overall post closure land use for Mogalakwena mine has been determined to be landforms that sustain indigenous vegetation to limit water and wind erosion. Nodes where existing infrastructure is utilised by stakeholders for a variety of activities and surrounding areas are expected to be rehabilitated back to a land capability possible of supporting indigenous vegetation, grazing as well as land capable of supporting the various community initiatives. Currently land-use related projects under the Impact Catalyst initiative are expected to align with the rehabilitation plan and economic diversification of the area. Neighbouring Ivanplats also plans to rehabilitate land to grazing capability. Table 3.25 shows the expected closure activities for both operations while table 3.24 shows proposals for post-closure by consultants SRK and Digby Wells.

Although the Mogalakwena area is an area of growth for the mining industry, and the operations have many decades yet before closure, there are many opportunities for developing activities that will support socio-economic development. These are summarised in Table 3.26

Table 3.24 Proposed closure plans for Mogalakwena (SRK, 2019; Digby Wells, 2016)

Mine	Land use	Infrastructure use
Mogalakwena	Mine impacted areas will be rehabilitated to landforms that sustain indigenous vegetation to limit wind and water erosion (includes vegetation to support grazing).	Flat areas where infrastructure is decommissioned will be converted to land for industrial and agricultural usage.
	Land use initiatives (incl. game farming and agriculture) are developed in specific areas as part of Impact catalyst development projects.	Infrastructure where there is a third-party use will be legally transferred to the relevant third parties
Ivanplats	Implement progressive rehabilitation measures where possible. Backfilling identified as a possible waste rock management strategy for the mined out underground areas. Reactive rock may, however, result in the risk of formation of acid mine drainage (AMD). AMD risk currently under assessment.	Potential land uses to be identified in future, where no sustainable use for mine infrastructure is identified, infrastructure will be demolished to avoid it being vandalized.
	Re-establishment of the pre-mining land capability to allow for a suitable post mining land use. Final land use to grazing capabilities within the areas where surface infrastructure will be (excludes Tailings Storage Facilities).	
	Maintain and minimise impacts to the functioning wetlands and waterbodies within the area.	

Table 3.25 Local economic development projects in Amplats and Ivanplats SLPs 2016-2020 for Mogalakwena

Land	Mooihoek Integrated Game Farm co-development Impact Catalyst initiative aimed at exploring the game farming and alternative agricultural value chain opportunities. Feasibility stage, currently managed as a game ranch with Armoede community to be the ultimate beneficiaries.
	Agro-processing and biodiesel production facility - Impact catalyst initiative aims to undertake technical feasibility assessments comprising pre-feasibility of primary production, feasibility of agro-processing, conduct design of the agro- processing and biodiesel facility
Enterprise development	ICT training and internet café (enterprise and skills development project) in the Molekane community providing connectivity and computer access, printing and value-added business services and skills development. Profit from business services expected to be ploughed back directly or into other community initiatives. Target beneficiary/community: Molekane community. Budget: R1.5mn. Project timeline: 2017-2020.
	Zimele SMME Mogalakwena business support (launched in 2018 administered by Absa Bank) - aims to build SMME capability outside of the mine value chain by providing business development services, mentorship training and access to funding. Project timeline: ongoing since 2018.
Infrastructure	Solar street-lights project to improve visibility in villages. Target beneficiary/community: Ga-Molekana, GaChaba, Skimming and Leruleng villages. Budget: R23mn. Project timeline: 2016-2020, project and maintenance to be handed over to Mogalakwena Local Municipality.
	Ga-Pila Sanitation project – Construction of 50 m^3/day mobile wastewater treatment plant with a back-up generator for Ga Pila village. Includes supply of 7,000 ℓ sucker to pipe waste from the septic tanks and transport to the wastewater treatment plant. Target beneficiary/community: Ga-Pila village. Budget: R5.5mn. Project timeline: 2017-2020, project to be handed over to Ga-Pila Community Trust.
	Mogalakwena water provision project to supply water to 35000 people in the Mapela Community (22 villages) as part of MLM Water Master Plan. Target beneficiary/community: Mapela Community (22 villages). Budget: R32mn. Project timeline: Project will be run and operated by a Special Purpose Vehicle (with 40% Community ownership) for at least 10 years.
	Construction of water and sanitation infrastructure for schools across Mapela and Mokopane. Project in partnership with has in partnership with Mogalakwena Local Municipality and the Department of Education will identify schools in dire need for water provision and sanitation. Target beneficiary/community: Ga-Manuel, Malepetleke, Ga-Masenya, Machikiri, Armoede. Budget: R7.9mn. Project timeline: 2016-2020.
	School upgrades and extension: Additional classrooms and admin blocks at John Pedro, Langalibalele, Mphunye, Maleya and Malepetleke schools. Target beneficiary/community: 5 villages in Mapela. Budget: R15mn. Project timeline: 2017-2020.
	Construction of the New Seritarita School. Target beneficiary/community: Skimming Village, Mogalakwena. Budget: R5mn. Project timeline: 2017-2020.
	Special presential package infrastructure projects - projects are infrastructure and basic services initiatives to support Public Private Partnerships and a transformation of communities. Target beneficiary/community: Mogalakwena local municipality. Budget: R15mn. Project timeline: 2017-2020; commitment pending as Waterberg district has not yet identified projects for development.
	Construction of Mmalepetleke sports complex. Target beneficiary/community: Mmalepetleke and surrounding villages; Mosesetjane, Sansloot, Mokaba, Magongwa. Budget: R8.7mn. Project timeline: 2017-2020; Municipal council resolution to begin construction was only secured in Q4 2021

	Tshamahansi Clinic Construction - Ivanplats and Anglo Platinum agreed to jointly invest project funding for larger clinic facility in the Tshamahanshi Village. Target beneficiary/community: Tshamahanshi Village. Budget: R25mn (Anglo Platinum share of funding of total R50mn project investment). Project timeline: 2021-2025.
Services	Health Care Clinics capacity support - two clinic projects which form part of the 2010-2015 SLP in the Sekuruwe and Naledi communities will be further supported to ensure they meet the Ideal Clinic standard while also acting as hubs to help strengthen surrounding facilities. Target beneficiary/community: Sekuruwe and Naledi - Mogalakwena/ Aganang. Budget: R3mn. Project timeline: 2017-2020.
	Support to improving health services in schools - partnership with Departments of Health and Basic Education. Target beneficiary/community: Mogalakwena/ Aganang local municipalities. Budget: R3mn. Project timeline: 2017-2020.
	Support to community home based care program to improve health care capacity and create opportunities for women and youth. Target beneficiary/community: Molekane community. Budget: R4mn. Project timeline: 2017-2020; programme to be transitioned to DoE.
Education & Skills development	Learner development and material supply - project to support the Department of Education to build content & pedagogical knowledge/capacity of teachers, content knowledge of learners & management capability of school leadership. Target beneficiary/community: Mahwelereng, Mogalakwena Local Municipality. Budget: R25mn. Project timeline: 2017-2020.
	Early Child development support programme: health and nutrition and the leadership and character teaching addresses, life skills, leadership, moral regeneration, virtue development, service and volunteerism. In the process it also capacitates teachers and parents. Target beneficiary/community: Over 44 schools in Mapela. Budget: R14.8mn. Project timeline: 2017-2020; programme to be transitioned to DoE.
	Municipal capacity development – Anglo American Capacity development program, plans to make a contribution to strengthening capabilities in the MLM with regards to strategic water management, infrastructure asset lifecycle management and strategic development planning. Target beneficiary/community: Mogalakwena Local Municipality. Budget: No stated. Project timeline: 2021, ongoing.

Table 3.26 Summary of land use opportunities identified in the Mogalakwena area

Land use category	Description
Agriculture	Cattle Farming, game farming, crops
Industrial	Agro-processing, Biodiesel, Hydrogen production
Renewable energy	Solar PV plants
Water reservoir	Existing dam
Community & culture facilities	Heritage sites
Conservation	Nature reserves

3.6 Conclusion

The learnings from the various case studies provide insight into current and emerging mine closure and post-mining land use approaches, the opportunities, challenges and influencing factors across social contexts, regions and different stages of life of mine. The COP projects provides insight into using industrial crops such as fibre crops for both rehabilitation and the creation of downstream industries due to their ability to form multi-products from fibre and phytoremediation potential. The Bokamoso Ba Rona project, though still in its early stages, gives insight on a potential approach for using mine-impacted land as well as land owned by mining companies to create large-scale regenerative agricultural projects, including crops and livestock. The project's multi-stakeholder collaboration across industry, local government, and government agencies also sheds some light on the roles and responsibilities of the different actors in the development of post-mining industries. The Green Engine case study examines an approach that integrates post-mining land use, agriculture water treatment, waste management and industrial development. However, the project has faced a number of challenges due to vandalism and illegal mining around the closed Kromdraai shaft where the various elements of the project were being developed. The Impact Catalyst project at Mogalakwena operation provides learning on early-stage project development for an operation with a significant life of mine. The integrated game farming, agriculture, and agro-processing development initiatives are expected to align with rehabilitation plan of the mine.

Learnings across the projects show that various influencing factors such as social contexts, land capability, soil quality, climate, water supply and treatment and local economic development need to be considered in planning for mine closure and post-mining land use development. There are several common land use opportunities across the projects that have been identified such as agriculture, agro-processing, livestock, game farming. However, the options around agriculture and crop selection and the potential to develop downstream agro-processing value chains need to be further understood. Other key opportunities that have emerged are around water treatment, renewable energy projects and the potential for energy provision post-closure. Despite the various identified opportunities and increasing effort to consider more holistic regenerative post-mining development initiatives, there continues to be a lack of integration in social development initiatives, rehabilitation and post-mining development, which continues to pose a risk to long-term regional development beyond mining activity. There also continues to be uncertainty on the continuity of projects when assets are bought by another company, which often happens when mines near their end of life.

CHAPTER 4: MINE CLOSURE RISK RATING SYSTEM FOR SOUTH AFRICA

4.1 Introduction

One of the main objectives of this project is to develop a mine closure risk rating system for South Africa that uses a comprehensive database of relevant parameters for all operating mines, describes methodologies for calculating mine closure risk, and incorporates expert input and community perspectives. This chapter describes the database, the draft mine closure risk rating system and the stakeholder engagement. The rating system was also tested using the case studies described in Chapter 3. The dataset of operating mines has been developed over the past five years by the lead author (Cole, 2023; Cole et al., 2023; Cole and Broadhurst, 2022, 2021) and expanded based on more recent information. It includes mine name, previous/alternative name, location, commodity, owner, operator, start date, life of mine, processing plant, farm/s and other relevant information. The social risk assessment relies on datasets for mining host communities and local municipalities, also developed by the lead author over time. These include population, households, type of community, location, and indicators of social and economic well-being. The mines and communities are summarised in Table 4.1 and Table 4.2 below.

Table 4.1 Summary of all operating mines in South Africa

Commodity	Operating Mines	Companies	Communities*	Population in 2011
Gold	33	8	61	1 538 739
Coal	78	32	89	2 638 804
Platinum	46	14	127	1 081 691
Chromium	21	11	50	680 638
Diamonds	9	6	21	498 645
Iron ore	7	8	6	92 339
Manganese	20	18	8	37 765
Vanadium	2	2	3	70 055
Copper	1	2	18	70 312
Nickel	1	1	1	582
Lead-Zinc	2	2	2	2 262
Titanium	4	3	3	63 193
Fluorspar	3	3	2	16 092
Phosphate rock	2	2	9	138 377
Rare earth minerals	1	1	1	650
TOTAL	230	104	367	6 243 010

*Note some communities have more than one commodity

Table 4.2 Summary of all mining host local municipalities and metropolitan municipalities

Province	Number of municipalities	Municipal population in 2022	Number of operating mines
Free State	5	859 736	13
Gauteng	9	14 966 638	19
KwaZulu-Natal	8	1 910 224	10
Limpopo	10	2 008 369	38
Mpumalanga	14	3 360 406	70
North West	8	2 481 414	46
Northern Cape	10	750 156	30
Western Cape	2	223 678	4
TOTAL	*66*	*26 534 859*	*230*

4.2 Methodology

Risk is the possibility or likelihood of loss or harm and incorporates exposure to a hazard. In this project three components of risk are being assessed for all operating mines in South Africa: the likelihood of mine closure, the socio-economic risk of mine closure and the environmental risk of mine closure. Each component has a set of influencing factors that were identified through literature review (Chapter 2), the case studies (Chapter 3) and engagement with experts. Each influencing factor was measured using one indicator, with the criteria for indicator selection being: 'Is the indicator the best available direct measure of the influencing factor?' and 'Are there sufficient reliable data that are measured on a regular basis?' Data to measure the indicators were then either collected from existing datasets or through research. The primary datasets are the 230 operating mines, the 350 mining host communities and 68 municipalities described above. Secondary data were collected from numerous open-source national datasets identified below. Each indicator received a weighting based on their estimated level of influence. These indicators for each component were then combined to create an overall rating and categorised as 'very low', 'low', 'medium', 'high' or very high' based on analysis of all the mines and sub-division into five quintiles of roughly equal numbers. These categories were colour-coded with cool to warm colours and plotted on maps in ArcGIS.

The draft risk rating was then tested on the four case studies and refined. A draft risk rating was presented to the project reference group (comprised of eight academics and industry experts) for feedback and to a group of experts at an online stakeholder engagement workshop conducted via Zoom. Over 70 experts in the mining industry, consulting, academia, civil society, and government, were invited to the workshop however only 15 attended on the day. Participants were asked to complete a survey during the workshop using Zoom's Advanced Poll functionality with 10 questions about the draft risk rating system. Semi-structured interviews were also conducted with experts in government and multilateral agencies to further refine and improve the rating system. The expert feedback on influencing factors and indicators was used to revise and improve the risk rating system and additional indicators were included. This final mine closure risk rating system is summarised in Figure 4.1. It is important to note that this is intended as a first version of a proposed risk framework for South Africa, and it is expected that it will be reviewed and improved over the years to come.

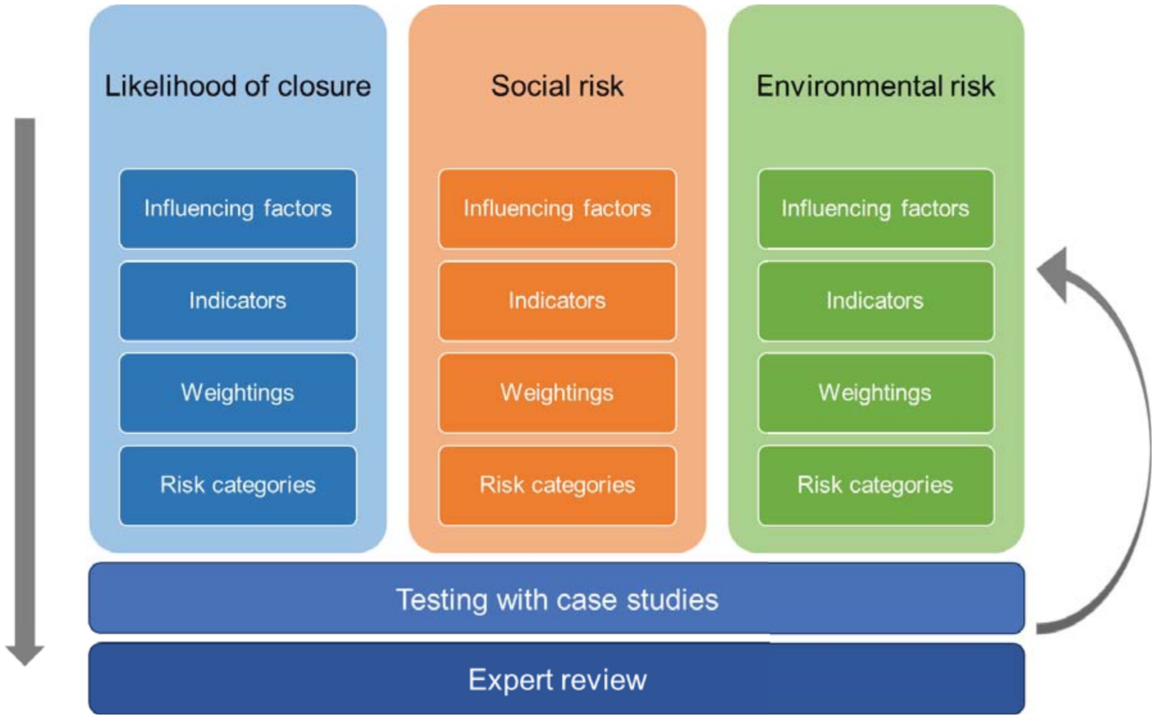


Figure 4.1 Overview of proposed mine closure risk rating system

4.3 Likelihood of mine closure

There are numerous economic, technical, social, environmental and governance factors that can influence when a mine closes. The major causes are resource exhaustion or depletion; high costs, price drops, or declining grades[3]; and loss of markets; while other causes are voluntary administration; adverse geological and/or geotechnical factors; flooding/inrush; government/political decisions; and safety/health or environmental issues (Laurence, 2006). Some factors cannot be measured but rather forecast with varying degrees of uncertainty, such as metal price and social unrest (Lèbre *et al.*, 2021). We have identified five factors that can be quantified, taking care not to create duplication. Each indicator is described in detail in the sub-sections below.

[3] Grade is the concentration of metal or mineral of interest in rock

Table 4.3 Risk rating system for likelihood of mine closure

Indicator	Risk rating					Data source	Weighting
	1 – Very low	2 – Low	3 – Medium	4 – High	5 – Very high		
Life of Mine	> 50	20-50	11-20	5-10	<5	Company reports	0.5
Commodity market outlook	High growth	Growth	Stable	Decline	Rapid decline	Industry analysis	0.15
Ore reserves and Resources	Very large	Large	Moderate	Limited	Very limited	Company reports	0.15
Mining method (operating cost)	Dredging	Strip	Open pit	Mechanised underground	Conventional underground	Company reports	0.1
Company type	Major		Junior		Emerging miner	Bloomberg	0.1

4.3.1 Life of Mine

Mining companies usually state the 'life of mine' (how many years of mining are left) for each of their operations on their websites, in their Social and Labour Plans and/or in their annual reports on mineral resources and reserves (MRR). The Life of Mine (LOM) is based on the latest assessment of their mineral resources and mineral reserves and is essential information for mine planning, investor reporting and for mining host communities, particularly those who heavily rely on the mine. It includes detailed assessment of economic, financial, technical and environmental factors and is normally reviewed annually. It is the most important factor in determining likelihood of closure. Not all mines publish their life of mine figures (although they are included in Social and Labour Plans which are meant to be publicly available) and where there were gaps, the highest risk rating was given, assuming the mine is small-scale with a short life of mine.

4.3.2 Commodity market outlook

South Africa mines over 20 major commodities – gold, platinum, palladium, rhodium, chromium, coal, diamonds, iron ore, manganese, vanadium, copper, nickel, lead, zinc, fluorspar, phosphate, heavy minerals ilmenite, rutile and zirconium, and is opening a rare earths mine dominated by neodymium. Each one of these commodities has different domestic and international markets that influence the commodity price and future demand, and thus the economic value of each mine's ore resources and reserves. This then influences the life of mine and the expected date of closure. Changes in the commodity markets have a significant impact on when a mine closes, and whether that is permanent or temporary closure. For example, when the tin price crashed in the 1970s tin mines closed down rapidly across the world (Falcon, 1985) and the huge variations in the gold price have seen mines close and reopen as viability changes (Marais, 2013). Mines can be placed on care and maintenance when there is a drop in prices but reopen when it improves. With the threat of climate change and the need to reduce GHG emissions, coal mines are likely to close sooner than expected, whereas copper mines are reopening as demand rapidly increases (Valenta *et al.*, 2019) and new manganese mines have opened up rapidly in South Africa (Koovarjee et al., 2023). As there is so much uncertainty in the future commodity markets, we have given each commodity a rating based on whether they are 'high growth', 'growth', 'stable', 'decline' or 'rapid decline'. These ratings are shown in Table 4.4 along with their data sources.

Table 4.4 Rating categories for commodity markets

Commodity	Rating category	Data sources
Thermal coal	Rapid decline	World Bank
Metallurgical coal	Stable	World Bank
Gold	Stable	S&P
Diamonds	Stable	Fortune Business Insights
PGMs	Growth	Green hydrogen
Chromium	High growth	World Bank Minerals for Climate Action
Vanadium	High growth	World Bank Minerals for Climate Action
Iron ore	Growth	Yale Major Metal Scenarios
Manganese	Growth	Yale Major Metal Scenarios
Copper	High growth	Yale Major Metal Scenarios
Nickel	High growth	Yale Major Metal Scenarios
Lead	High growth	Yale Major Metal Scenarios
Zinc	High growth	Yale Major Metal Scenarios
Fluorspar	Growth	Future Market Insights
Titanium	Growth	World Bank Minerals for Climate Action
Phosphate	Growth	Future Market Insights
Rare earth	High growth	World Bank Insights for Climate Action

4.3.3 Mineral Resources and Reserves

The SAMREC Code sets out minimum standards, recommendations and guidelines for Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves in South Africa. It has been drawn up by the SAMREC Committee of the SAMCODES Standards Committee under the joint auspices of the Southern African Institute of Mining and Metallurgy (SAIMM) and the Geological Society of South Africa. The purpose of international reporting codes is to ensure that misleading, erroneous or fraudulent information relating to mineral properties is not published and promoted to investors on the stock exchanges. The use of the SAMREC Code allows the investor or potential investor to assess the asset and compare it to other assets to other opportunities. This technical reassurance is grounded in the scientific and engineering basis for the declaration (SAMREC, 2016). The SAMESG guideline defines the key ESG aspects which influence the reasonable prospects for eventual economic extraction as well as the Modifying Factors which include closure and rehabilitation, and risk (SAMESG Committee, 2017). The framework of the SAMREC code (Figure 4.2) has three main categories that represent a progression from little information and thus low confidence in the basic geology, to significant information and the ability to demonstrate economic viability.

- An Exploration Result is the lowest category of declaration where some preliminary geological work has been undertaken suggesting possible interest in the orebody.
- A Mineral Resource estimate is developed once further scientific and engineering work is done and a geological model is developed, with geological and/or grade continuity and reasonable prospects for eventual economic extraction. These can be inferred, indicated or measured.
- A Mineral Reserve is declared once technical (including mining, processing, metallurgical, infrastructure), economic, marketing, legal, environmental, social and governmental factors – collectively known as the Modifying Factors – have been considered, designed, engineered and costed and shown to indicate an economically feasible project. These can be either probable reserves or proven reserves, based on the level of knowledge.

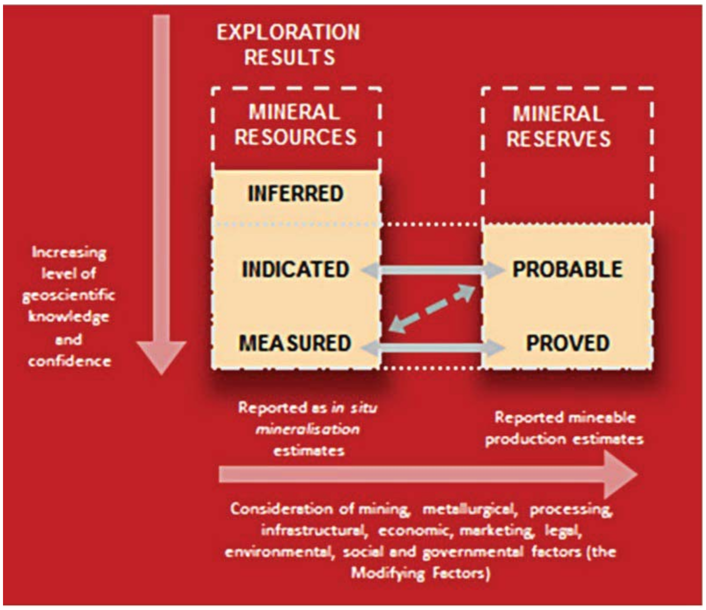


Figure 4.2 Framework for the SAMREC Code (SAMCODE, 2022)

As different commodities use different units in their reporting due to the nature of the orebodies (e.g. million tonnes for coal but ounces for gold), we have not used volumes or weights in the rating but rather the five terms 'Very large', 'Large', 'Moderate', 'Limited' or 'Very limited', to provide a relative rating for mineral resources and reserves for each mine, shown in Table 4.3. This is based on a review of the latest company annual MRR reports. Where no MRR was reported, the highest risk rating was given as it is likely that it is a smaller mine with limited reserves.

4.3.4 Operating costs and mining methods

The operating costs of mining operations vary widely due to many factors such as the head grade, mining methods, depth of operation, recovery rate, work labour efficiency and the use of subcontractors (Lonergan, 2006). Costs are also affected by the price of input commodities such as fuel, electricity, labour, chemical reagents, explosives, steel and concrete. Deep underground operations tend to be high-cost operations as they require additional infrastructure such as refrigeration for ventilation and rock support. Mechanised operations tend to be lower unit cost operations because of their associated opportunity for economies of scale. Mineral processing or treatment costs vary depending on the type of ore and the complexity of the onsite process, with heap leach operations generally being low-cost operations (Rudenno, 2012).

Weak mineral commodity prices in the early 1980's led to greater cost consciousness among mining operators and this attitude extended into investment analysis (Gentry and O'Neil, 1984). As a result of inaccurate price forecasts at the time, investors looked for more investment criteria, focussing increasingly on the competitive cost rankings of prospective mines. Some investors even required that new projects be in the lower cost region before committing funds into the project. It has since become standard practice in the mining industry to plot industry cost curves which can be constructed and analysed at a company or country level to facilitate mining costs comparison on a national, regional, or international level (Raab and Steinnes, 1993; Tholana et al., 2013; Atta and Tholana, 2022). Cost curves help various stakeholders (investors, analysts, and mine management) to evaluate the cost ranking of a mine or company in the industry.

Companies or mines are placed on a cost curve according to their production on the horizontal axis and their cost on the vertical axis. The larger producers tend to inhabit the lower quartile of the cost curve, while the smaller producers dominate the upper quartile, as shown in a typical commodity cost curve in Figure 4.3 below. Figure 4.4 provides an example of a cost curves platinum mines categorised by quartile.

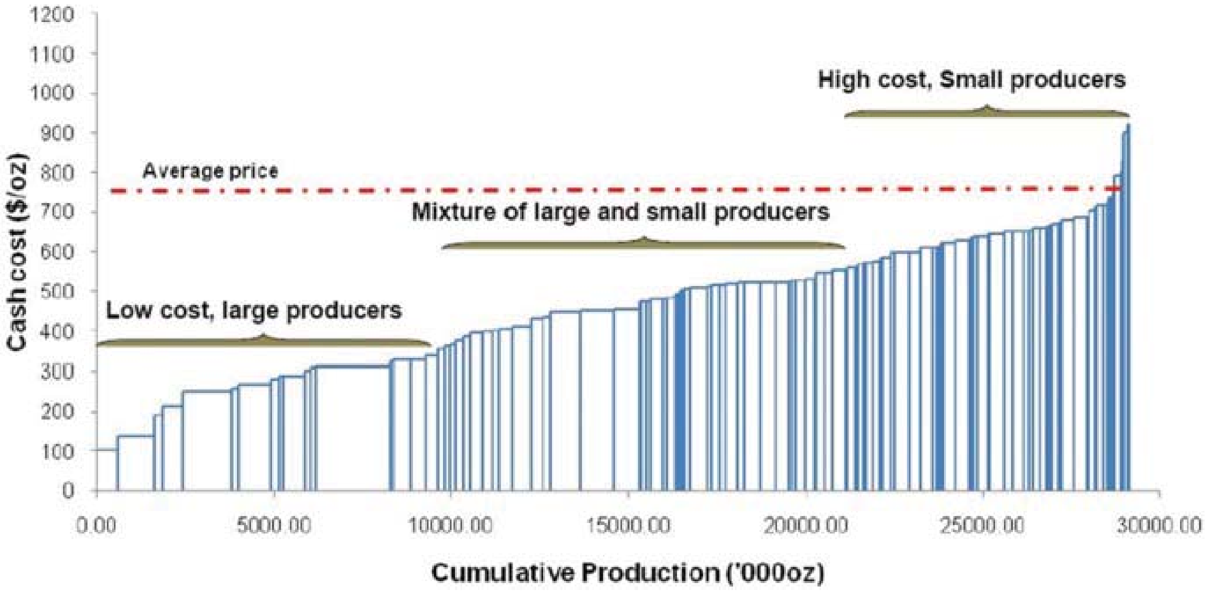
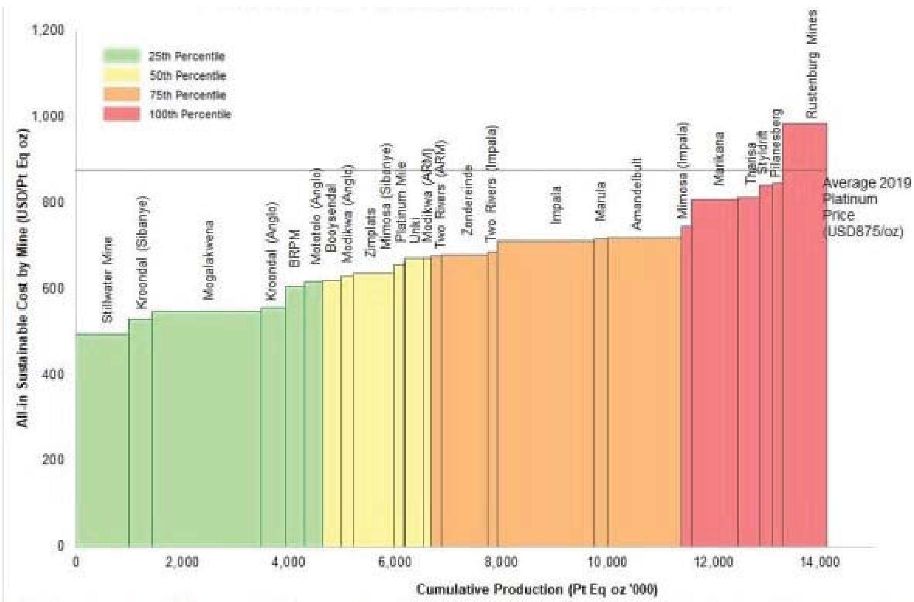


Figure 4.3 A typical industry cost curve (Tholana et al., 2013)



Disclaimer: Information displayed in graph is based on public information collected from the South African PGM mining company's annual reports. There is no guarantee that the interpreted information is 100% accurate.
Note: JV costs may differ due to companies reporting different costs or production figures, or financial years not lining up.

Figure 4.4 Southern African platinum mines cost curve for 2020 (Minxcon, 2021)

As we were unable to obtain sufficient cost curves to generate a rating, we used mining method as a proxy for operating cost. We differentiated between five main kinds of mining methods used in South Africa:

- *Open pit mining* maintains exposure to the surface throughout excavation and usually has stepped sides for safety and wide ramps for equipment travel. This is usually used for low-cost, low-grade deposits. It is also called open cast mining.
- *Strip mining* involves removing a strip of overburden (waste) before mining a seam of ore and is the most common method in coal mining.
- *Dredging* is a surface mining method uses small dredges to suction ore from aquatic environments like ocean or river floors. It is often used for diamonds and heavy mineral sands.
- *Conventional underground mining* is used for deeper deposits and entry from surface is from horizontal adits, vertical shafts or declines. This is usually used for higher grade deposits as it is higher cost. Specific methods include room and pillar mining (commonly used for coal) and narrow vein stoping (used for gold and platinum).
- *Large-scale mechanised underground mining* is used for large deposits and includes long-wall mining, sub-level caving and block caving (used for coal, diamonds and copper).

4.3.5 Company type

The type and size of a company partly determines its ability to accommodate changes in price, demand, operating costs, and other factors that affect a mine's financial viability. The larger companies are much more likely to weather a downturn than the smaller mining companies. Internationally, mining companies are categorised as majors, mid-tier producers and juniors. Majors usually have a market capitalisation of over USD 1 billion. The term "junior mining" generally refers to exploration or prospecting companies only involved in the early stages of mining development. This is particularly true for Canada, however, in Australia, junior mining usually refers to mid-tier producers. In South Africa the term junior mining has taken on a wider meaning and includes exploration companies and mid-tier producers. The term "emerging miners" is indigenous to South Africa and typically refers to smaller companies involved in the early phases of mining exploration or in the early developmental stage, i.e. smaller producing companies and contractors (Minerals Council, 2021). This is captured in the rating in Table 4.3. These three categories used – majors, juniors and emerging miners – are based on the Minerals Council report on junior and emerging miners which categorises all operating mines listed by the DMRE (ibid).

4.3.6 Social licence to operate

The relationship between the mining company and the local community can be a risk to mine operations. Protests about environmental pollution, damage, noise, jobs and local procurement are common in South Africa and are known to bring operations to a halt and result in significant loss of revenue, jeopardising the viability of the mine. Ideally we would measure protests per mine across the country, however, this data is not currently available in a comprehensive form and was thus excluded from the rating system.

4.3.7 Political dynamics

National and local politics can promote or hinder investment in mining operations, with corruption, political interference, political instability and regulatory uncertainty all deterring investment in mine expansions, and thus leading to premature mine closure. The regulatory uncertainty and national politics apply equally to all mines in the country so are not included as an indicator. It is difficult to measure political dynamics at the local level thus an indicator has not been included at this stage but should be investigated further.

4.4 Social risk of mine closure

As described in the literature review (Chapter 2), mine closure can have significant social impacts, including direct and indirect job losses; economic downturn in the communities and even the wider region; basic services disruption if the mining company was supporting or supplying services; and illegal mining which creates an unsafe environment for local residents. The exposure to these hazards depends on how many people are affected, i.e. the population of mining host communities, and it is therefore very important how they are defined. The vulnerability or resilience (social well-being) of a community affects how well it can cope with the economic shock of mine closure – whether it is sudden or a long time in coming. Similarly, the capacity of the local government authority affects its ability to cope with mine closure and the resulting loss of revenue. The direct job losses obviously have a major impact on the employees affected, while the impact on the wider community is partly determined by the mine's economic contribution to the local economy (measured in Gross Value Add, GVA, or Gross Domestic Product, GDP) and the type of community, such as a mining town, economically diverse city or remote rural village. We have thus defined seven parameters to measure the social impact of mine closure and these are shown in Table 4.5. Each one is described in detail in the sub-sections that follow.

Table 4.5 Risk ratings for social impacts of mine closure

Indicator	Risk rating					Data source	Weighting
	1 – Very low risk	2 – Low risk	3 – Medium risk	4 – High risk	5 – Very high risk		
Community population	< 5,000	5,000-30,000	30,000-60,000	60,000-100,000	> 100,000	Census 2011	0.1
Social well-being	> 7.3	6.8-7.3	6.4-6.8	5.8-6.4	< 5.8	Census 2011	0.3
Dependency ratio	40-46	47-49	50-54	55-65	66-84	Census 2022	0.1
Direct jobs in mining and quarrying	< 1000	1,000-5,000	5,000-15,000	15,000-30,000	> 30,000	Census 2011	0.3
Remoteness of community (Distance to city)	0-25 km	25-50 km	50-75 km	75-100 km	> 100 km	Google Maps	0.1
Local municipality audit finding	Clean	Unqualified	Qualified	Adverse	Disclaimed *or* Not finalised	Auditor-General reports	0.1

4.4.1 Mining host community population

We have identified the mining host community for each mine based on its location and proximity to the mine, whether it is home to mining employees or is a beneficiary of the mine's Social and Labour Plans, and an assessment of the community and area in Google Earth. Setting a specific radius was not used as it can exclude communities that are close neighbours to other communities included in the definition. The ratings given in Table 4.5 for population were based on analysis of all the communities and sub-division into five quintiles of roughly equal numbers.

4.4.2 Social well-being

Fourteen indicators were identified and measured to determine a score for social well-being in each mining host community, expanding on previous work by the authors (Cole and Broadhurst, 2021, 2022; Cole, 2023; Cole et al., 2023). The indicators selection was based on the Sustainable Development Goals (SDGs), the South African Index of Multiple Deprivation, SAIMD (Wright and Noble, 2009) and on data availability at the local level, i.e. in the national census. The indicators are given in Table 4.6. and cover income (SDG 1), household goods (SDG 1), health (SDG 3), education (SDG 4), gender equality (SDG 5), water access (SDG 6.1), sanitation (SDG 6.2), electricity access (SDG 7.1), clean cooking fuel (SDG 7.1), employment (SDG 8), housing (SDG 11.1), refuse removal (SDG 11.6), safety (SDG 16) and internet access (SDG 17). Main place and sub place data in StatsSA's SuperCross Census 2011 Community Profile Database were obtained from DataFirst at UCT, which provides online access to household survey data in South Africa and Africa (DataFirst, 2015). The individual values were equally weighted and combined into an overall well-being score.

Table 4.6 Indicators of social well-being for mining host communities

SDG	Dimension and SDG target	Indicators
1 No poverty	Income (SDG 1.2)	% households with income more than R19,600/year (estimated national poverty line)
	Household goods	% households that own a refrigerator
2 Zero hunger	Food security (SDG 2.1)	*% of people who are undernourished**
3 Good health	Health	% population without a disability
4 Quality education	Education (SDG 4.1)	% adults (age 20 or older) with NQF4 qualification (Grade 12, NTC3) or better
5 Gender equality	Gender representation (SDG 5.5)	% of female councillors in local government
6 Clean water and sanitation	Water access (SDG 6.1)	% population with piped water in their dwelling or yard
	Sanitation (SDG 6.2)	% population with access to a flush toilet or chemical toilet
7 Affordable and clean energy	Electricity access (SDG 7.1)	% population with access to electricity
	Clean cooking fuel (SDG 7.1)	% population using clean cooking fuel
8 Decent work and economic growth	Employment (SDG 8.5)	% labour force (including discouraged jobseekers) employed
11 Sustainable cities and communities	Housing (SDG 11.1)	% population in formal housing
	Waste management (SDG 11.6)	% population with refuse removal
16 Peace, justice and strong institutions	Safety (SDG 16.2)	*% population in local municipality who feel safe walking in their neighbourhood in the day**
17 Means of implementation	Internet access (SDG 17.8)	% population with access to internet

**no local data found*

4.4.3 Direct jobs

The more mine workers there are in a community, the bigger the social impact will be when a mine closes. Although most of the major mining companies report the current number of employees in their annual reports and on their websites, the junior and emerging miners do not and it is very difficult to obtain the figures. Instead, the Census 2011 data on employment in mining and quarrying per local municipality were used. This is not ideal as it gives much higher numbers than the individual mine accounts for, and thus it has been given a low weighting. This dataset should be updated when the Census 2022 community database and ideally the analysis should be done at the main place level. An alternative indicator is the percentage of jobs in mining and quarrying, to reflect the varying impact on the area. Future research should seek to obtain job numbers for individual mines.

4.4.4 Indirect jobs

Operating mines form part of a much bigger value chain, relying on upstream and downstream industries. They have a multiplying effect on employment which can be estimate at the national and regional level. Data do not exist yet at the mine site level and therefore were not included in the rating.

4.4.5 Local economy

Gross domestic product (GDP) is the total monetary or market value of all the finished goods and services produced within a region's borders in a specific time period. It is the most commonly used measure of a country's economic health. Gross value added (GVA) is an economic productivity metric that measures the contribution of a corporate subsidiary, company, or municipality to an economy, producer, sector, or region. GVA provides a Rand value for the amount of goods and services that have been produced in South Africa, minus the cost of all inputs and raw materials that are directly attributable to that production. GVA thus adjusts GDP by the impact of subsidies and taxes (tariffs) on products. GDP and GVA are usually reported on an annual basis. Mines make significant contributions to the local municipality that they are located in. This is sometimes reported in IDPs or in reports commissioned by mining companies. We could not find a complete data set for this so it will require further research. As not all IDPs report this figure, an alternative dataset was used. stepSA provides local economic data in a national spatial dataset using CSIR's mesozones (a complete grid of 25 ,000 spatial units, not uniform in shape but approximately the same size (~50 km^2) and economic data by sector (STEPSA and CSIR, 2018). This gives an indicator of economic production per sector (excluding construction) expressed in Rands per mesozone.

4.4.6 Dependency ratio

The dependency ratio relates the number of children (aged 0-14) and the number of older persons (aged 65 and over) to the working age population (persons aged 15-64). The ratio highlights the potential dependency burden on workers – a high dependency ratio indicates that the economically active population and the overall economy face a greater burden to support and provide the social services needed by children and by older persons who are often economically dependent (UN ESA, 2007). This ratio was calculated for all local municipalities using the census 2022 community database and categorised as shown in Table 4.8.

4.4.7 Skills and education levels

The skills and education levels of mine workers and community members will affect their ability to find employment or create a business after the mine has closed down. Social and Labour Plans provide details information about skills levels of all mine employees, however the majority of SLPs are not publicly available. There is no national skills dataset that could be used for the mining communities thus research is needed before this can be included in the rating.

4.4.8 Crime and Safety

Illegal mining and the associated crime can be a consequence of mine closure. Some commodities like diamonds and gold are more prone to illegal mining as the valuable minerals and metals are easy to extract. The approach taken by the national and local police force is critical in whether illegal mining takes place but is hard to measure. Illegal mining often opens up mine shafts and pits to the public which poses a safety hazard. Similarly, poorly rehabilitated mines can also pose safety and health risk to mining communities but is hard to predict. There is no available national dataset and is an area for future research.

4.4.9 Local municipality audit finding

Each year the Auditor-General of South Africa (AGSA) assesses the financial state of all of the country's municipalities and rates them according to the following definitions:

- *Financially unqualified opinion with no findings (clean*): the municipality's financial statements were free of material misstatements, quality performance reports that measure and report on performance in a manner that is useful and reliable, complied with key legislation.
- *Financially unqualified opinion with findings*: the municipality was able to produce quality financial statements but struggled to produce quality performance reports and/or to comply with all key legislation.
- *Financially qualified opinion with findings*: the municipality's financial statements contained material misstatements that were not corrected before the financial statements were published. The municipality also had challenges with the quality of the performance report and/or compliance with key legislation.
- *Adverse opinion with findings*: the municipality's financial statements contained so many material misstatements that we disagreed with virtually all the amounts and disclosures in the financial statements.
- *Disclaimed opinion with findings*: could not provide us with evidence for most of the amounts and disclosures in the financial statements.

In 2021, only four of the 64 municipalities that hosted operating mines achieved a clean audit (6%), while two had an adverse opinion, five had a disclaimed opinion and five had not finalised the audit yet (Auditor-General South Africa, 2022). These are shown in Table 4.7 which indicates that most municipalities are in financial distress and will not be well placed to cope with mine closure. The five categories were used in the risk rating in Table 4.5.

Table 4.7 Audit findings of all local municipalities that host operating mines in South Africa

Province	District Municipality	Local Municipality	Population in 2022	Audit finding in 2021
Free State	Fezile Dabi	Metsimaholo	158 391	Qualified
		Moqhaka	155 410	Qualified
	Lejweleputswa	Masilonyana	63 800	Qualified
		Matjhabeng	439 034	Not finalised
	Xhariep	Letsemeng	158 391	Qualified
Gauteng	City of Johannesburg*	City of Johannesburg*	4 803 262	Unqualified
	City of Tshwane*	City of Tshwane*	4 040 315	Unqualified
	Ekurhuleni*	Ekurhuleni*	4 066 691	Clean
	Sedibeng	Emfuleni	945 650	Unqualified
		Midvaal	112 254	Clean
	West Rand	Merafong City	225 476	Adverse
		Mogale City	438 217	Unqualified
		Rand West City	334 773	Qualified
KwaZulu-Natal	Amajuba	Dannhauser	142 750	Qualified
		Emadlangeni	36 948	Qualified
		Newcastle	507 710	Unqualified
	Umzinyathi	Endumeni	100 085	Qualified
	uThungula	uMhlatuze	412 075	Unqualified
		uMlalazi	241 416	Clean
	Zululand	Abaqulusi	247 263	Qualified
		Ulundi	221 977	Unqualified
Limpopo	Capricorn	Blouberg	192109	Unqualified
	Greater Sekhukhune	Elias Motsoaledi	288049	Unqualified
		Fetakgomo Tubatse	575 960	Unqualified
	Mopani	Ba-Phalaborwa	188 603	Qualified
	Vhembe	Musina	130 899	Unqualified
	Waterberg	Bela-Bela	64 306	Qualified
		Lephalale	125 198	Unqualified
		Mogalakwena	378 198	Qualified
		Thabazimbi	65 047	Qualified
Mpumalanga	Ehlanzeni	Thaba Chweu	98 387	Unqualified
		City of Mbombela	67 156	Unqualified
		Nkomazi	591 903	Unqualified
	Gert Sibande	Chief Albert Luthuli	247 664	Unqualified
		Govan Mbeki	310 117	Qualified
		Lekwa	119 669	Disclaimed
		Mkhondo	255 411	Unqualified
		Msukaligwa	199 314	Qualified
		Dipaleseng	35 980	Disclaimed
	Nkangala	Emakhazeni	50 165	Adverse
		Emalahleni	434 522	Qualified
		Steve Tshwete	242 031	Clean
		Thembisile	431 248	Unqualified
		Victor Khanye	106 149	Qualified
North West	Bojanala	Kgetlengrivier	54 759	Disclaimed
		Madibeng	522 566	Disclaimed
		Moses Kotane	265 668	Qualified
		Rustenburg	562 315	Qualified
	Dr Kenneth Kaunda	City of Matlosana	431 231	Unqualified
	Ngaka Modiri Molema	Mafikeng	354 504	Qualified
		Ramotshere Moiloa	161 605	Not finalised
		Ratlou	128 766	Disclaimed
Northern Cape	Frances Baard	Dikgatlong	56 967	Qualified
	Frances Baard	Sol Plaatjie	270 078	Qualified
	JohnTaolo Gaetsewe	Gamagara	29 580	Qualified
	JohnTaolo Gaetsewe	Ga-Segonyana	117 454	Unqualified
	JohnTaolo Gaetsewe	Joe Morolong	125 420	Not finalised
	Namakwa	Khâi-Ma	85 10	Qualified
	Namakwa	Nama Khoi	67 089	Not finalised
	Namakwa	Richtersveld	24 235	Qualified
	Siyanda	Kgatelopele	19 854	Not finalised
	Siyanda	Tsantsabane	30 969	Qualified
Western Cape	West Coast	Matzikama	69 043	Clean
	West Coast	Saldahna Bay	154 631	Clean

* Metropolitan municipality

4.5 Environmental impacts of mine closure

As described in the literature review (Chapter 2), mine closure can have significant environmental impacts on biodiversity, land and water resources and involving water pollution, air pollution and land degradation, as discussed in Chapter 1 of this report. Determining a risk rating for each mine is complicated due to the mismatch of scales and the uncertainty over extent of impact. We identified nine influencing factors but could only find national datasets to measure six of them, shown in Table 4.8 and described in the sub-sections below. Data were collected from the South African National Biodiversity Institute (SANBI), the South African Department of Forestry, Fisheries, and the Environment (DFFE), the South African National Roads Agency (SANRAL), and the South African Environmental Observation Network (SAEON). The datasets were converted into a consistent format and georeferenced in ArcGIS. The capacity of government to monitor and enforce environmental regulations was not included as a factor as it is a national government function and therefore the same for all mines.

Table 4.8 Risk ratings for environmental impacts of mine closure

Parameter	1 – Very low risk	2 – Low risk	3 – Medium risk	4 – High risk	5 – Very high risk	Data source	Weighting
Duration of mining	0-25 yrs	26-50 yrs	51-75 yrs	76-100 yrs	>100 yrs	authors research	0.1
Distance to nearest protected area	>40 km	20-40 km	10-20 km	5-10 km	0-5 km	GIS calculation	0.1
Terrestrial ecosystem threat status	Least concern	Vulnerable		Endangered	Critically endangered	SANBI 2018	0.2
Distance to nearest Strategic Water Source Area	>40 km	20-40 km	10-20 km	1-10 km	0-1 km	GIS calculation	0.1
Mine water threat	Low	Moderate Low	Moderate	High	Very high	WRC 2018	0.3
Land capability	VIII Wilderness	VI-VII Grazing land	IV Marginal land	III Moderate potential	I-II High potential arable land	DAFF 2012	0.2

4.5.1 Duration of mining

The longer a mine has been operating, the greater the likelihood of environmental impact. We have determined the start date of each mine, and any periods of temporary closure, to calculate the total duration of mining for each mine. We then converted this into a risk category as shown in Table 4.8.

4.5.2 Distance to protected areas

Mining often operates near biodiversity hotspots and protected areas. In South Africa protected areas are defined and maintained by the DFFE and SANBI. The authors' mine location dataset was overlaid on the protected areas shapefiles provided by SANBI's BGIS and the distance from each mine to the nearest protected area was measured in ArcGIS. This was converted into a risk category as shown in Table 4.8

4.5.3 Terrestrial ecosystem threat status

The National Biodiversity Assessment of 2018 identified areas of different ecosystem threat status across the country for terrestrial, aquatic and marine ecosystems (Skowno et al., 2019). The authors' mine location dataset was overlaid on the shapefiles provided by SANBI's BGIS to determine the terrestrial threat level and assigned a risk rating as shown in Table 4.8.

4.5.4 Distance to Strategic Water Source Areas

Mining often negatively impacts on local and regional water resources. In South Africa surface and groundwater Strategic Water Source Areas (SWSA) have been identified. The SWSA shapefiles provided by BGIS and the authors' mine location dataset were used to measure the distance from each mine to the nearest SWSA in ArcGIS, and then categorised as shown in Table 4.8.

4.5.5 Mine Water Threat

The South African Mine Water Atlas presents mineral risk profiling or rating in key thematic maps regarding "mineral provinces", "mineral risk", "mining activity risk", "groundwater vulnerability", "surface water threat" and 'mine water threat" (WRC, 2018). Mineral provinces are regarded as mineralised zones that are similar in terms of their host rock geology and mineralogy. Mineral risk maps indicate the assessed risk of acid production and/or leaching of constituents. Mining activity risk maps indicate the assessed relative risks against the dominant mining methods associated with mineral extraction. Groundwater vulnerability and surface water threat maps reflect the vulnerability of those water sources to mining activities. These threats are rated from 'low or insignificant' to 'moderate low' to 'moderate' to 'high' and to 'very high'; higher scores present relatively higher risk or vulnerability ratings. The groundwater vulnerability rating is based on the type of mining activity as the depth of mining is considered to have major varying impacts on aquifer systems. The groundwater vulnerability ratings are therefore separated into surface mining (<100 m below ground level) and underground mining (>100 m below ground level). The threat posed to surface water resources is reported at the quaternary catchment scale that lie within the boundary of the assessed mineral provinces. Each of the component risk profiles can be mapped and understood individually or combined as "mine water threat" mapping. The WRC's Mine Water Threat risk ratings were determined for each mine on a series of thematic maps layered individually for groundwater (surface mining), groundwater (underground mining) and surface water. These three ratings were combined to give a cumulative mine water threat rating and categorised as shown in Table 4.8.

4.5.6 Agricultural production and land capability

Agriculture can be significantly hindered by mining and mine closure, through water and air pollution and land degradation. The current agricultural production gives an indication of the potential negative environmental impact of mine closure. We could not source sufficient data to measure agricultural production at the local level, so instead we used South Africa's national land capability classification (described in Chapter 2 and Table 2.4) which uses soil, climate and terrain to differentiate between arable land suitable for cultivation (classifications I, II and III), marginal land suitable for light cultivation (classification IV) grazing land (classification V, VI and VII) and wilderness (classification VIII). Mine locations were overlaid on the national land capability map in ArcGIS provided by the DFFE to determine the land capability class for each mine and risk categories were assigned as shown in Table 4.8.

4.5.7 Waste stability

Most large-scale mines produce significantly more waste than economic minerals and billions of tonnes of mine tailings (a slurry of rock, water and chemicals) are stored every year in dams or tailings storage facilities (TSFs) and are a source of disaster risk and pollution (Owen et al., 2020). Climatic, topographic and tectonic factors play a role in the stability of TSFs, including exposure to earthquakes, tropical cyclones, high winds, heavy rainfall, and steep terrain (Lèbre et al., 2020). These five factors can be measured with global datasets and combined to form a TSF failure risk rating. This was not included in this version of the rating system due to an incomplete TSF dataset and is an area of future research.

4.5.8 Volume of waste

The total volume of rock waste dumps (million tonnes) and tailings at each mine affects the potential environmental impact in terms of water pollution, dust pollution and risk of failure (Owen et al., 2020). Some of this data is available through the Global Tailings Portal but it is not a comprehensive national dataset. This is a very difficult parameter to measure, and other research projects are underway in different parts of the country to do this (e.g. Koovarjee et al., 2023).

4.5.9 Capacity and approach of mining company

The capacity and management approach of the mining company responsible for closure will determine the effectiveness of rehabilitation and water and waste management during the closure process. This is difficult to measure and an indicator was not included at this stage but should be investigated and the presence of a risk assessment in the mine closure plan assessed. The financial provisions for each mine, a regulatory requirement, should give an indication of the ability of the mine to undertake effective rehabilitation but the data is hard to find and requires further research.

4.6 Results of Risk Rating

4.6.1 Likelihood of Closure

The likelihood of closure rating was calculated for all operating mines and the results are displayed on the map in Figure 4.5. There were some data gaps and, particularly around life of mine and mineral reserves for the junior and emerging mining companies, in these cases, the highest rating was given as they usually have smaller mines. The initial results were reviewed against case studies and it became clear that the weightings needed to be adjusted. The map shows clearly the high risk of closure in the Mpumalanga coal fields, the majority of gold mines in Gauteng, Free State and North West provinces, and a few chromium and platinum mines in the North West province. The minimum rating was 1.2, the maximum rating was 4.8 and the average was 3.3. Of the 32 mines with a ‘very high’ rating, 29 are coal mines and three are gold mines. The mines with ‘high’ ratings are predominantly coal, gold and chromium mines, along with 10 relatively new manganese mines operated by emerging junior miners with limited published information, which may skew the results.

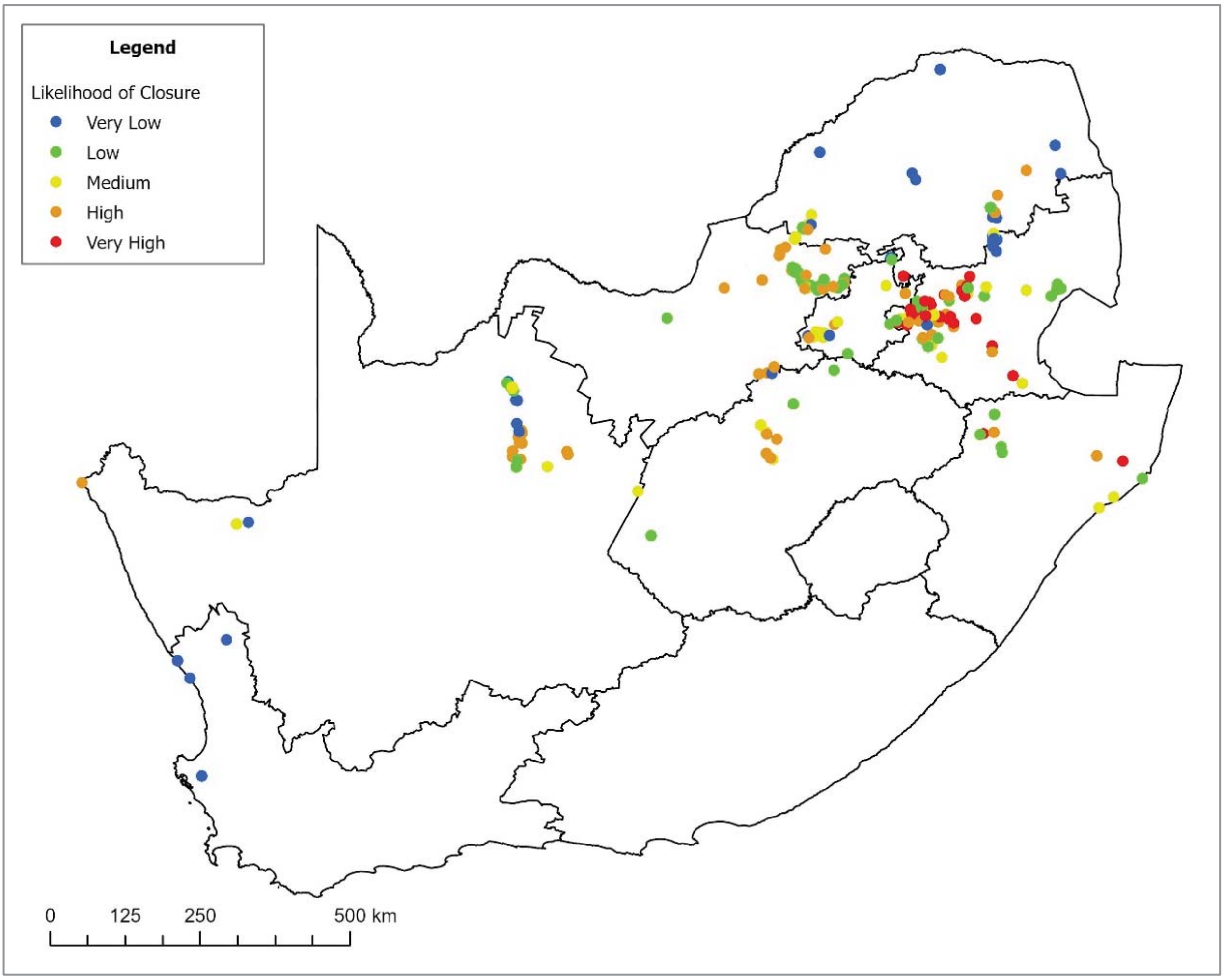


Figure 4.5 Likelihood of Mine Closure Rating for all operating mines in South Africa

4.6.2 Social impact of closure rating

The social impact of closure rating was calculated for all operating mines and the results are displayed on the map in Figure 4.6. The map shows highest risk for mines surrounded by rural villages and lowest for mines near to cities. The mines with the 'very high' ratings are almost all platinum and chromium mines in North West and Limpopo provinces, as they are surrounded by deprived rural villages and have very large workforces. Notable exceptions are the copper and phosphate mines in Phalaborwa, which are two of the most remote mines, and two coal mines in eastern KwaZulu Natal, which all have deprived rural communities. The manganese mines in Northern Cape have a 'high rating' due to their deprived rural communities and remote location. Although most gold mines have large workforces, their communities are better off with lower dependency ratios, and they are close to cities, so they have a 'Medium' rating. Similarly, the remaining of coal mines are categorised as 'Low' or 'Very low' because they are hosted by small towns near cities, with higher levels of wellbeing and lower dependency and their workforce is relatively small compared to gold and platinum. These ratings are a first attempt at a national comparison of social risk and will require further testing and analysis in the future.

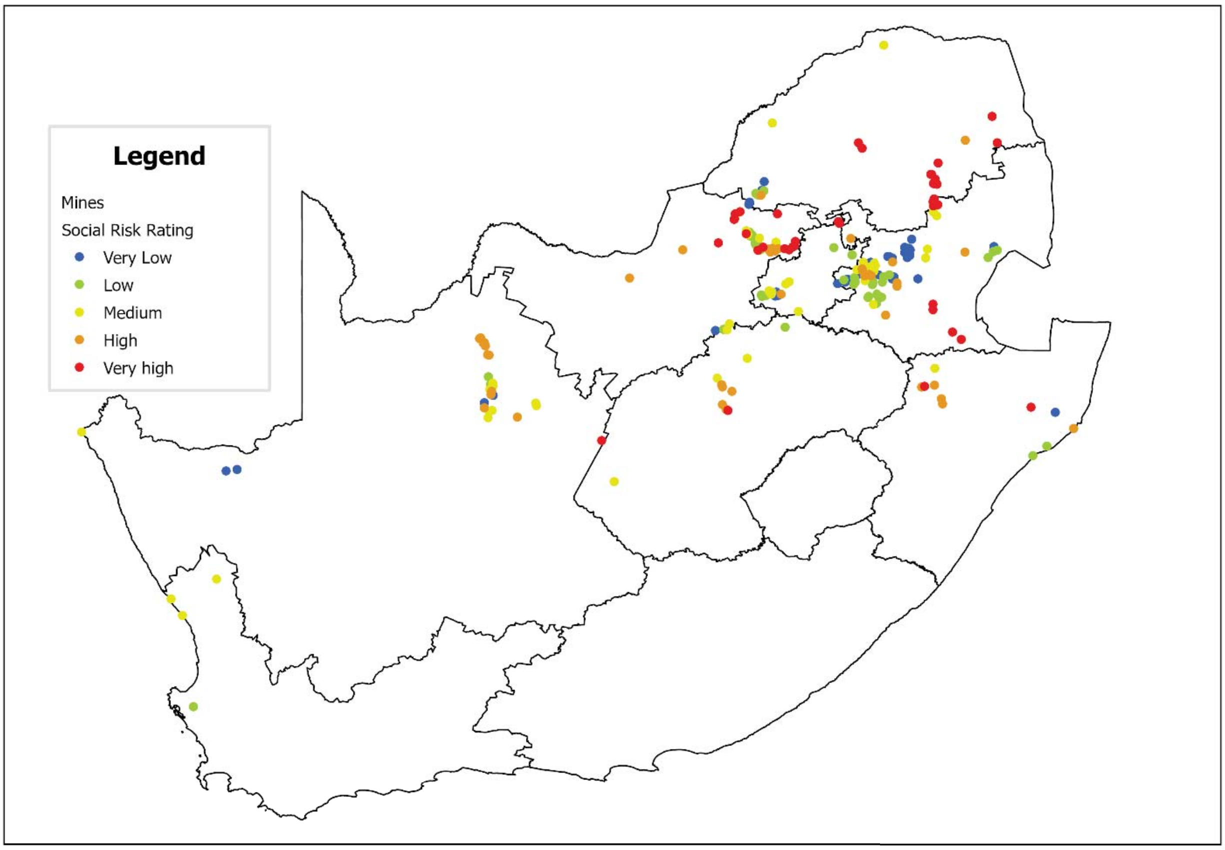


Figure 4.6 Mine Closure Social Risk Rating for all operating mines in South Africa

4.6.3 Environmental impact of closure rating

The environmental impact of closure rating was calculated for all operating mines and the results are displayed on the map in Figure 4.7. The map shows very high and high risk for gold and coal mines because of the risk of acid mine drainage to the water resources and degradation of arable land. There are several platinum mines on the Western Limb in North West province that also receive a high rating largely due to the threat to arable land, terrestrial ecosystems and protected areas. The lowest risk areas are in the Northern Cap, where there is no arable land and the least threatened ecosystems, and Limpopo, where the mine water threat is low and no endangered ecosystems.

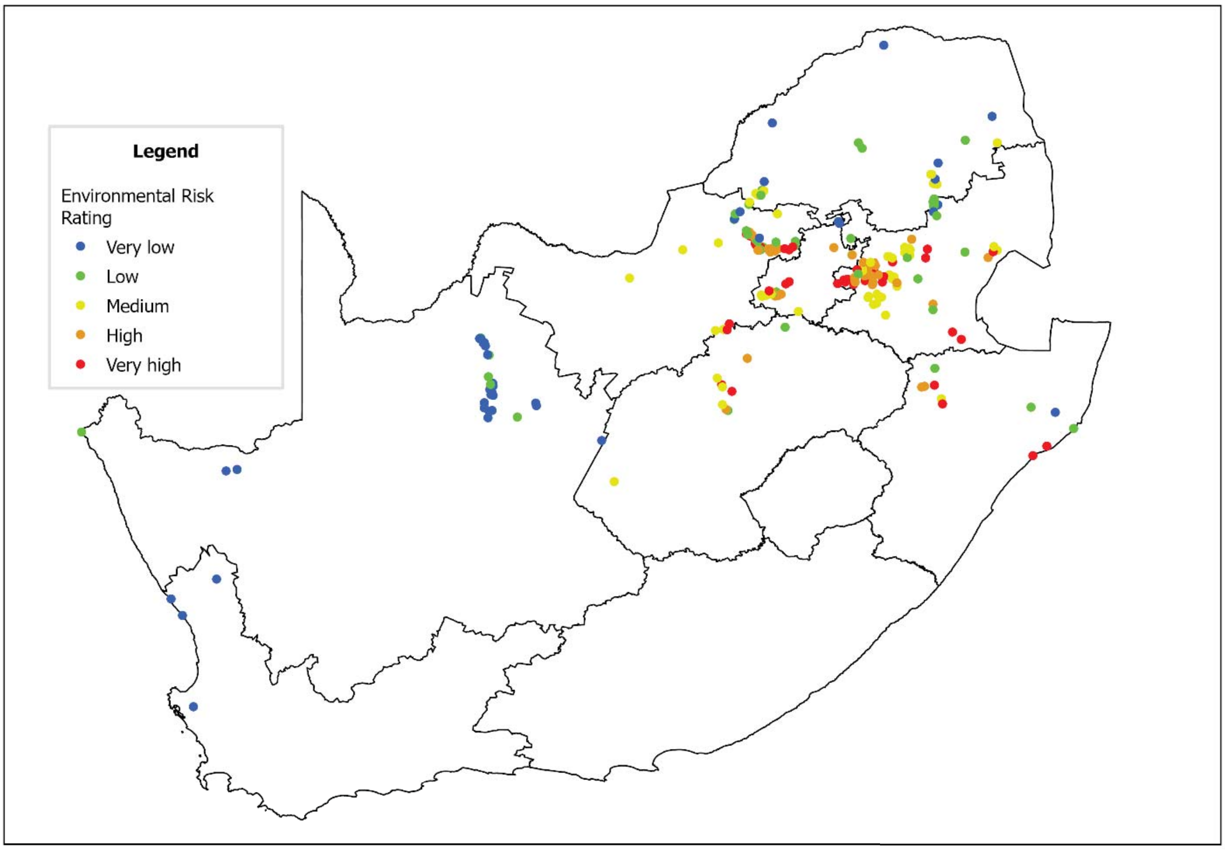


Figure 4.7 Mine Closure Environmental Risk Rating for all operating mines in South Africa

4.6.4 Case studies

In order to test the draft rating system, the three ratings were calculated for all mines in the case studies described in Chapter 3 which have very diverse mine plans, social contexts and environmental settings, ensuring robust testing of the ranges and categories. The results given in Table 4.9 show very high likelihood of closure for Khwezela, high likelihood for Kusasalethu which is due to close next year but has ore reserves that could extend the mine plan to 2037 if economic and political conditions improve (Digby Wells, 2022), medium for four other gold mines, low for the three new mines (two being highly mechanised gold mines that previously closed due to low gold price and high operating costs), and very low for Mogalakwena which has a life of mine of over 70 years and low operating costs. The social impact risk ranges from low risk in some gold mines, with relatively better off communities located near the Gauteng metropolitan areas, to very high risk in Mogalakwena platinum mining areas in Limpopo, where the mines are surrounded many very deprived communities with high dependency ratios. The environmental risk ratings range from are very high for the gold mines located in Strategic Water Source Areas or areas with more threatened ecosystems or better arable land, to low in the Mogalakwena platinum mining area where there are low threats to water resources and ecosystems and the mines have been operating for a much shorter time.

Table 4.9 Risk ratings for all mines in the case studies

Mine	Commodity	Mine type	Mining region	Likelihood of closure rating	Social risk rating	Environmental risk rating
Mogalakwena	Platinum	Open pit	Northern Limb, Limpopo	Very low	Very high	Low
Ivanplats		Mechanised underground		Low	High	Low
Mponeng	Gold	Conventional underground	Far West Rand, Gauteng	Medium	Low	Medium
Blyvoor				Low	Low	Medium
Kloof				Medium	Medium	High
Driefontein				Medium	Medium	Very high
Kusasalethu		Mechanised underground		High	Low	Medium
South Deep				Low	High	High
Doornkop		Conventional underground	West Rand, Gauteng	Medium	Medium	Very high
Khwezela	Coal	Open cast	Witbank, Mpumalanga	Very high	Medium	High

4.6.5 Summary

This chapter has described the development of three novel mine closure risk ratings for all operating mines in South Africa. The likelihood of closure map identifies mines and areas where mine closure is highly likely and needs immediate attention. The social risk and environmental risk maps enabling the prioritisation of mitigation and intervention by mining companies and government. While numerous indicators could be measured and quantified with existing or developed national datasets, there were important gaps and opportunities for adding further aspects to the risk ratings. The risk ratings proposed here are a first attempt at a national comparison of likelihood of mine closure, social risk and environmental risk, and will require further testing and analysis in the future. Additional datasets will be required to fill gaps and ensure that the risk ratings capture all of the influencing factors. The results of the risk ratings could promote deeper discussions on mine closure management and planning amongst a diverse group of stakeholders, and support evidence-based decision-making.

CHAPTER 5: MINE CLOSURE OPPORTUNITIES FRAMEWORK

5.1 Introduction

One of the main objectives of this project is to produce a post mine closure opportunities framework for South Africa. As described in the literature review in Chapter 2, there are several existing decision-making tools, methodologies and frameworks that can be learned from and applied to mine closure in South African. These tools involve multi-criteria decision-making and the selection of suitable options from finite sets of alternatives according to environmental, technical, socio-economic criteria. Of particular interest in this study was the framework developed by Amirshenava and Osanloo (2018) which integrates mine closure risks with post-closure land use selection, and was supported by Cui et al. (2020) who suggested that mine closure risks should inform post-closure land use options. Manero et al. (2020) and Arrati-Soler et al. (2022) highlight that multi-decision criteria frameworks for post-closure land use are often hindered by the subjective nature of criteria ranking and the methodological complexity, therefore we decided to develop a simple framework that outlines the comprehensive process for identifying the most suitable land-use options, rather than a ranking system. The aim of this procedural framework is to ensure that all land-use options are considered, all stakeholders are able to participate and all relevant national and local influencing factors are taken into account. This was supported by the lessons learnt from the case studies described in Chapter 3 that showed four different approaches to post-closure land use development, with varying degrees of success, and the engagement with experts throughout the study.

5.2 Developing the Framework

The proposed post-closure land use framework was developed based on the literature review, insights from the case studies and engagement with experts through 25 semi-structured interviews and 15 participant observation at dialogues (detailed in Appendix A). The process of developing the framework entailed evaluating the findings against a set of key questions. The key questions are:

- What are the overall aims and objectives of post closure mine rehabilitation and land use?
- Who needs to be involved in the process of selecting suitable land use alternatives?
- How can the needs and desires of the host mining community be given voice?
- What are all the possible land use alternatives?
- What factors influence the final decision for selecting a viable post-closure land use?
- What criteria or measurable indicators can we apply to these factors to aid decision-making?

Based on learnings and insights of the key questions, a 6-step procedural framework was developed to support the process of ensuring that all land-use options are considered, all stakeholders can participate, and all relevant national and local influencing factors are considered. The framework is shown in Figure 5.1 and described below:

> **Step 1**: Stakeholder mapping to identify stakeholders, interested and affected parties and voices necessary to support post-closure process. Convene a participatory process to determine the post-closure land use aims and objectives and desired developmental pathway. This will inform subsequent the engagement process and priorities for the influencing factors and key questions.

Step 2: Review all possible global and local land-use alternatives to determine the post-closure land use aims and objectives and desired developmental pathway. This will inform the continuous engagement process and priorities for the influencing factors/key questions.

Step 3: Understand the natural environment, and the land use suitability related to land capability, water availability and quality, and the renewable energy potential, and how these align with the desired developmental objectives.

Step 4: Consider how multiple socio-economic factors, such as community resilience and local economic activities, or impact the potential land use alternatives and the developmental objectives.

Step 5: Assess the range of governance factors which can support or limit the capacity to achieve the desired post-closure objectives.

Step 6: Determine the most suitable post-closure land uses in consultation with stakeholders and assess against desired aims and objectives.

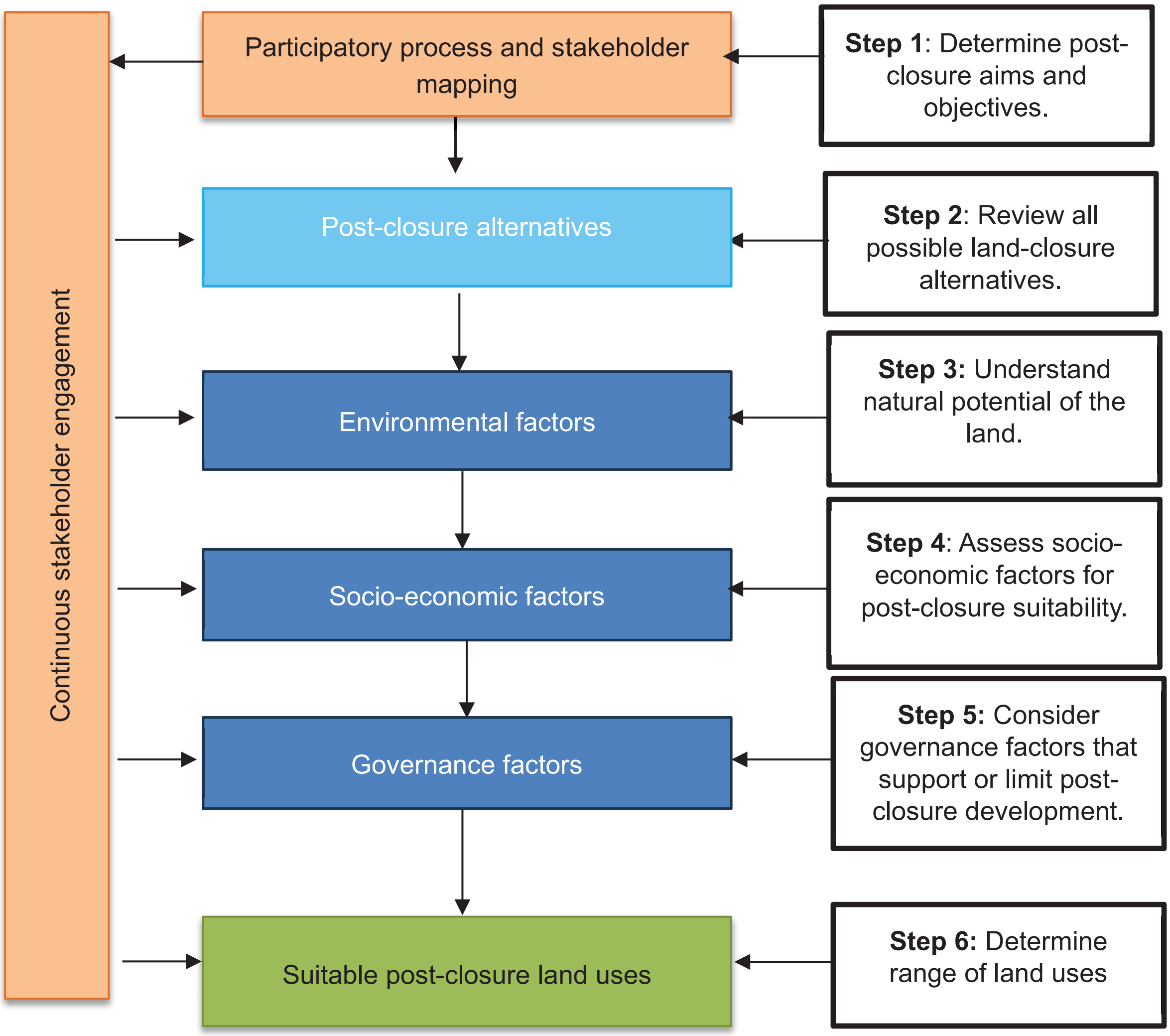


Figure 5.1 Proposed post-closure opportunities framework

5.2.1 Stakeholder Mapping

In South Africa currently public participation meetings and consultations are held to inform stakeholders on developments. Various provisions of the Mineral and Petroleum Resources Development Act, 2002 (MPRDA) require the holder of a mining right to notify or consult with the affected landowners or communities. However, based on the literature and insights from experts, current publication participation and consultation meetings do not support inclusive participation, decision-making and engagement. Experts, especially community support organizations, explained that stakeholders are often not informed in time of the public participation meetings, and key stakeholders and/or interested and affected parties are not included. Further to that, experts felt that the public participation meetings serve as information sessions rather than inclusive and collaborative engagement. So therefore, as part of the first step of the proposed post-closure land use framework, stakeholder mapping is required to ensure all affected parties are included in the process of selecting post closure land uses. Comprehensive stakeholder mapping is also helpful to analyse power dynamics and the relationships between different stakeholders to anticipate how that may affect the land-use decision making process. Stakeholder groups identified as essential for post-closure engagement include government at different levels, labour unions, industry and business, community groups and civil society, academia, investors and donor agencies.

5.2.2 Participatory process: setting aims and objectives

Determining post-closure objectives represents the difficult task of addressing the different needs and values of stakeholders but will improve the chances of success of post-closure transitions. Significant developmental transitions require the support and active participation of stakeholders. As earlier discussed in section 2.5.2 in the literature stakeholder participatory processes are increasingly being incorporated into post-closure land use decision-making and selection approaches (Rosa et al., 2018; Everingham et al., 2018, 2020). This is largely because different stakeholders often hold diverse priorities and perspectives that influence post-mining land use objectives and values on what constitutes the most desirable developmental transitions (Everingham et al., 2020; Measham et al., 2022). There are several different post-mining land use objectives for mining identified in the literature; namely, economic diversification, land-use efficiency, remediation and rehabilitation, job creation and resilient communities. Based on insights from the case studies, workshops and dialogues, while developmental pathways such as economic diversification and socio-economic development both support beneficial post-closure land use selections, stakeholder values and needs will ultimately influence which pathway is desirable and what objectives are prioritised.

Therefore, to support more inclusive decision-making in South Africa, a participatory process is essential for setting objectives of post-closure and determining the desired developmental pathway, for example, economic diversification based on national priorities or local economic development. The proposed framework seeks to emphasize that the initial participatory process to determine objectives and the desired post-closure developmental pathways needs to be differentiated from the continuous stakeholder engagement required to support the post-closure land use selection process. The aim of the initial participatory process is to;

- Identify post-closure objectives and priorities of each stakeholder group through an inclusive participatory process.
- Reach a consensus on shared shareholder objectives and values for post-closure development.
- Determine the developmental pathways that best align with the shared stakeholder values and needs for post-closure.

While this initial participatory process may require time and effort, establishing a shared post-closure vision builds the foundation for the subsequent steps in assessing influencing or limiting factors and ultimately determining the range of suitable land uses.

Post-closure land use alternatives need to be considered in the broader national, regional and local context of each mine site. While the mining company management may seek one goal, there are other aims and objectives to consider. An initial participatory process is required to determine the desired developmental pathway, which will lead to prioritising different screening questions. For example, if determined by the participatory process that the desired pathway for post-closure land use is socio-economic development then job creation should be a priority screening question under the socio-economic factors. Or, on the other hand, if economic diversification is the desired pathway, then skills level perhaps would be a first key question under the socio-economic factors. The framework developed in this chapter aims to conceptualise a post-closure land use framework which integrates current and emerging approaches specifically around decision-support and developmental narratives.

5.2.3 Continuous stakeholder engagement

Global closure guidelines, such as the ICMM's integrated mine closure good practice guide (2019) discussed earlier in section 2.2.2 of the literature, recommend that continuous stakeholder engagement is integrated into planning of activities throughout the mining cycle including in mine closure. Based on insights from experts, continuous engagement on mine closure currently in South Africa is inefficient and does not include all stakeholders. The post-closure framework recommends a continuous stakeholder process across the post-closure procedural steps to support the post-closure land use selection process. The continuous stakeholder engagement process should ensure objectives, previously agreed on in the initial participatory process, are addressed, decision-making at every step is inclusive, relevant influencing factors are prioritised and the scope of the developmental pathway is addressed by post-closure opportunities. General and specific land use alternatives.

Mining directly impacts land quality and land use, and invariably alters landscapes through activities such as vegetation cover removal, topsoil and overburden removal, water table disturbance and waste disposal. Land use planning assesses land potential, alternatives for land use, and economic and social conditions affecting options for land use (ICMM, 2019). A clear definition of post-mining land use greatly facilitates closure planning as it helps to define the site-specific vision and objectives and the definition of success criteria (ICMM, 2019). As described in the literature review in Chapter 2, there are several general post-closure land use categories, namely, agriculture, forestry, conservation and ecosystem services, industry, renewable energy, water supply, tourism, recreation, community and cultural facilities, and research facility, which have numerous specific land uses and global examples (see Table 2.2). One aim of the proposed framework is to act as a screening tool at the mine site level, enabling decision-makers to move from general ideas for post-closure, to viable options based on quantitative and qualitative criteria. The identification of all general and specific post closure land use alternatives ensures that 'pet projects' are not selected based on individual preferences. From the insights on the case studies specific land use alternatives important to South African context and development agendas were identified. Table 5.1 summarises the land use alternatives that emerged from the case studies.

Table 5.1 General and specific land use alternatives important for the South African context

Land use category	Description
Agriculture	Cattle Farming, game farming, industrial crops, fibre crops, eucalyptus trees, biomass crops, traditional food crops, animal fodder, greenhouses
Industrial	Agro-processing, Biodiesel, Bio-refinery, Hydrogen production, Biogas plant, Tyre pyrolysis, Waste recycling
Renewable energy	Solar PV plants, wind farms
Water reservoir	Existing dam, water catchment areas, water treatment plant

Community & culture facilities	Heritage sites, Accommodation, Historic sites
Conservation	Nature reserves, Protected sites

From the range of global land uses from literature and local land uses insights from the case studies, these can then be tested with a comprehensive set of influencing factors as part of Steps 3-5 of the procedural framework developed.

5.3 Land use suitability influencing factors

Based on findings from the mince closure risk ratings developed in Chapter 4, expert insights and literature on land use approaches, influencing factors for land suitability address closure risks and additional factors pertaining to the capacity to transition to a post-closure phase. Steps 2-4 of the procedural land use framework cover the land use suitability factors. These factors address environmental, social, economic, technical and governance considerations (including non-measurable parameters that are important but data are difficult to obtain (and beyond the scope of this project), and defined land use suitability indicators that can be measured based on publicly available data. This will ensure that the most promising post-closure land uses are selected based on the available evidence.

5.3.1 Natural environment

Understanding the suitability and/or capacity of the natural environment to support any land uses is critical to the implementation for post-closure land use, particularly in determining whether agriculture, forestry, conservation or renewable energy are feasible options for post closure land use. The environmental factors that can be measured across South Africa include land cover and land capability; water supply, water stress and water quality; nature reserves and protected areas, sensitivity from a biodiversity point of view; and solar and wind potential for renewable energy. These are shown in Table 5.1. As the factors influencing mine closure risk are very similar, most of these factors are described in the previous chapter. These factors need to be considered within local and regional contexts, current and long-term requirements. The key questions to consider for this step are as follows:

Land capability: What is the land capability based on the extent of rehabilitation of the site, land capability measures and current land cover?

Water availability: What is the current and long-term water availability, based on water stress, water quality and climate change, to ensure acceptable water volumes and qualities to support local use and potential post-closure land use?

Biodiversity and tourism: What are the biodiversity concerns requiring protection and maintenance of protected areas, and potential opportunities for tourism in post-closure land uses?

Energy potential: What is the energy generation potential to support current and long-term energy requirements in the area (locally and regionally) and post-closure land uses, and its feasibility based on existing infrastructure?

Table 5.2 Environmental factors for post mine closure land use opportunities

Influencing factors	Description	Suitability indicators	Data source
Land cover	SA land cover details land availability and condition of lands	Land cover classes across 73 categories	DFFE 2020
Land capability	The SA national classification includes soil, terrain (slope) and rainfall to determine 8 classes.	Land capability classification (Class I-VIII)	DAFF 2002
Water stress	Constraints on water supply	Municipal water stress	Cole et al., 2018
Water quality	Vulnerability of water resources to mining activity	Mine water threat status	WRC 2018
Biodiversity protection	Protected areas and conservation areas	Location of protected areas	SANBI 2018
Biodiversity loss	Threat status for ecosystems	Threat status of terrestrial ecosystems	SANBI 2018
Solar energy	Solar potential generation	Solar potential	Global Solar Atlas
Wind energy	Wind potential generation	Wind potential	Global Wind Atlas

5.3.2 Socio-economic factors

It is important to assess and consider the social and economic aspects related to land use opportunities at the site location. The influencing factors are infrastructure, local and regional economy, land ownership, community social wellbeing, skills, job creation and financial provisions (see Table 5.3). The priority of the questions will be highly influenced by the developmental pathway agreed on by stakeholders. The key questions to consider for this step are as follows:

Spatial context: What is the proximity to towns, cities, villages, to determine (a) settlement and housing needs and (b) access to markets for potential post-closure industries?

Infrastructure availability: What is the connectivity to existing infrastructure (roads, railways, energy networks) to identify possible infrastructure that could support post-closure industries?

Mine site infrastructure: What is the current inventory of mine site infrastructure to identify possible infrastructure that can be repurposed to support post-closure land uses?

Economic complexity: What is the diversity of the local economy to support linkages between current sectors and post-closure land uses/industries?

Land zoning and ownership: What is the land zoning and ownership structure, and how will it support or limit post-closure land use development?

Social wellbeing: What is the social wellbeing of the community to determine social needs that can be addressed by post-closure land uses?

Skills level: What are the skills levels to determine (a) current skills ability to meet post-closure land uses and (b) re-skilling requirements?

Job creation: What are the current direct jobs associated with mining activity to, (a) determine job creation needs and (b) align post-closure land use with job creation needs?

Financial provisions: What is the available financial provision set aside for closure and financial capital required for post-closure development?

The site location, particularly the distance to towns, cities, villages and the connectivity to existing infrastructure such as roads, railways, energy network partly determines what alternative post-closure land uses are possible. The site location can enable or be a barrier to access to markets and the creation of alternative economies, especially in building value chains for alternative industries. Assessing the infrastructure at the mine site presents opportunities to repurpose buildings and other infrastructure. Additionally, evaluating land ownership and zoning requirements at a site is necessary to establish potential opportunities or barriers to develop new land uses and the land transfer to new land users.

In terms of the local and regional economy, understanding the economic activity or economic complexity around a mining area or site is crucial to establishing opportunities to diversify into other industries. This is indicated by GDP or GVA contribution by different industries in a region. The higher the contribution by a single industry, in this case mining, indicates higher barriers to developing alternative post-closure economies. While an existing diverse economy indicates a higher potential to grow new or existing industries or capitalise on existing markets.

Assessing the social wellbeing of the community surrounding a mining area supports understanding potential socio-economic development opportunities, such as education and health care. In terms of skills for new industries, the level of education in a region indicates the availability for the existing workforce to support a new land use or determine level of re-skilling or upskilling needed for new land uses or economies. The direct jobs impacted by mining is a key indicator for determining the minimum post-closure job creation needs in mining areas, and informing the selection of land uses that promote job creation.

Evaluating the available capital for mine closure and post-closure development is essential in determining the capacity for a mining company to establish new land uses and the potential additional investment required. This can be assessed by the financial provision a company has set aside for closure and rehabilitation. Financial provision refers to the funds that are set aside, often in the form of insurance, bonds or guarantees, for mine closure activities. The lack of financial provision for closure activity limits capacity to develop post-closure activities which are capitally intensive.

To enhance the stakeholder engagement process of selecting and developing post-closure land uses, the frequency of community engagement by mining companies is an important indicator for existing community relations and the potential to support participatory processes. The relationship between the mining company and the local community can hinder or support mine closure activities and post-closure land use development.

Table 5.3 Socio-economic factors for post mine closure land use alternatives

Influencing factors	Description	Suitability indicators	Data source
Access to markets	Proximity to towns, cities, villages	Distance to nearest town/city (km)	GIS calculation
Existing public infrastructure	Existing infrastructure (roads, railways, energy networks)	Distance to existing infrastructure (roads, railways, energy networks)	DFFE
Mine site infrastructure	Mine site infrastructure and buildings	Potential to repurpose mine site infrastructure	GIS analysis
Economic complexity	Diversity of the local economy and linkages between sectors	GVA of municipality for mining and quarrying	CSIR 2018
Land zoning and ownership	Land zoning and ownership	Dominant land ownership (private, government, communal/traditional leaders)	DRDLR, deeds office, local municipalities
Social wellbeing	Community social wellbeing and vulnerability	Community social wellbeing and vulnerability indicators	Cole and Broadhurst, 2021, 2022
Skills availability	Skills availability and skills level	Percentage of adults with Grade 12 / NQF 4 as highest education level	SLP, Census
Financial provisions by mining companies	Financial provision for closure activities set aside by mining companies.	Rand value of financial provision for mining company	DFFE

5.3.3 Governance

Governance factors highly influence the capacity to develop post-closure land uses and to make the transition to alternative economic activities. The factors considered are legislative frameworks, local and regional government capacity, dynamics of traditional community leadership, land conflicts, corporate governance of the mining company, community agency and illegal mining activity. The key questions to consider for this step are as follows:

Legislative framework: What is the current legislative framework for mine closure and does it support post-closure land use development?

Local government capacity: What is the current performance of local government and does the local government have the capacity to support future post-closure industries?

District government capacity: What is the current performance of district government and does the district government have the capacity to support future post-closure industries?

Traditional leadership fragmentation and or contestation: Will the current traditional leadership structure hinder or support the post-closure transition?

Land conflicts: Are there any current or potential land use claims that will affect land use development?

Mine company type: Does the mining company have the capacity for responsible mine closure and post-closure transition?

Illegal mining activity: Are there any reports of illegal mining activity in the area that can hinder mine closure and post-closure development?

Community agency: Can the level of community agency and cohesion support or hinder post-closure transition?

Community Engagement: What is the frequency and extent of community engagement to support community involvement in post-closure development?

The current main legislative frameworks which govern mine closure in South Africa are the MPRDA 2002, NEMA and the amendment to financial regulations in 2023, and the NWA 1998. The Draft Mine Closure Strategy was released in 2021 to promote post-closure development and collaboration in mining areas and the revised strategy will need to be assessed. Though the dynamics of traditional community leadership may be difficult to evaluate in mining areas, traditional leadership fragmentation and or contestation needs to be considered as this can highly influence governance and community engagement on post-closure land uses. The community types and the number of traditional councils in a mining area can be used as a proxy to determine the potential complexity related to traditional leadership. Conflicts around land ownership can also potentially hinder the implementation of post-closure land use. The level of community agency in a mining area can support participatory processes to determine post-closure objectives and implement land uses. Potential indicators are the number of NGOs in a community, level of public engagement (e.g. social media visibility) of prominent people in the community, i.e. “Community champions”.

Table 5.4 Governance factors for post mine closure land use opportunities

Influencing factors	Description	Suitability indicators	Data sources
Legislation	Legislation pertaining to mine closure and land use	Implementation of legislation	DMRE, DFFE, DWS
Local government capacity	Local government capacity to facilitate and support new land uses	Financial audit result	AGSA
District government capacity	District government capacity to facilitate and support new land uses	Financial audit result	AGSA
Traditional leadership	Traditional leadership fragmentation and or contestation over land use and its benefits	Number of traditional councils involved	DALRRD
Land conflicts	Land under land claims in the area	Percentage of land under land claims	DALRRD
Mine company type	Size and type of mining company	Market cap of mining company	Bloomberg
Community engagement	Community engagement practices of the mining companies	Frequency of community engagement	Community support group reports
Illegal mining	Illegal mining activities of closed mines in the region, or the same commodity	Illegal miners operating in the region and/or commodity	Media reports
Community agency	Community agency and cohesion	Social media engagement, Champion for change, Number of NGOs active	

5.4 Determining the suitable post-closure land uses

To determine the suitable range of post-closure land uses which align with potential developmental pathways, screening questions across steps 3-5 would have to be applied iteratively in line with developmental priorities and continuous stakeholder engagement. Initial iterations would first determine general land uses alternatives and then subsequent iterations can enhance the process of narrowing down specific land uses. The final list of options would then be assessed from a financial point of view to determine whether they are economically viable and to identify potential sources of public and private investment and whether mechanisms like public-private partnerships will be necessary.

This process will allow mining companies to generate socially acceptable and economically viable projects that will support the continued development of the area around the mine beyond the life of mine. This will meet the aims and goals of the Social and Labour Plans, the Mine Closure Plans and the broader agenda of the industry to contribute to sustainable development in their host communities.

CHAPTER 6: MINE CLOSURE ATLAS FOR SOUTH AFRICA

6.1 Introduction

Geographic Information Systems (GIS) are conventionally used in the mining industry during the exploration phase of a mine, for the development of Environmental Impact Assessments (EIAs), and for mine management (Werner et al., 2019). However, GIS can also be used to evaluate mining conditions; identify suitable mine models for construction; display geochemical and hydrological data; optimize the management of facilities and policing; aid applications for mining permits; manage land titles; process closure; identify suitable reclamation activities; and improve community education (Esri, 2018). All operations in GIS are done with the utilisation of geographically referenced data (Harris & Weiner, 1998). The complex anthropogenic characteristics of the mining industry cannot be fully developed without GIS (Andreev, 2021). It has benefits at all scales – it can be used for environmental and socio-economic risk assessments at a local scale; cumulative and strategic impact assessments at a regional scale; and for analysing industry-wide land use trends, for comparative analyses of impacts across commodities, locations, and mine configurations at a global scale (Werner et al., 2019). Furthermore, the use of GIS supports the ICMM Conservation of Biodiversity principle by aiding the assessment of risks and impacts to biodiversity and ecosystem services, which paves the way for identifying methods of implementing the mitigation hierarchy to achieve no-net-loss of biodiversity (ICMM, 2023). The importance of GIS in mining is evident in the growing number of GIS-based assessments of mining and datasets related to mining (Luckeneder et al., 2021, Maus et al., 2022, Tang & Werner, 2023, Geoscience Australia, 2023). As part of this study, a novel Mine Closure Risk and Opportunities Atlas for South Africa was developed as an online and interactive map tool which displays mining, social, economic, environmental, governance and demographic datasets that are relevant to mine closure and post-closure land use and used to calculate the risk ratings described earlier in this report.

6.2 Creating the Atlas

The Atlas was developed based on the premise of the concept of a 'Creative Technologies' (CT) design process, which aims to improve the quality of life through product and application design that builds on information and communication technology. The design process hosted by CT consists of four phases: 1) ideation; 2) specification; 3) realisation; and 4) evaluation (Mader & Eggnik, 2014). Thus, an iterative approach was undertaken to develop the Atlas. All the datasets used in the risk ratings and identified in the post-closure land use opportunities framework were collated and converted into a consistent format and georeferenced. The risk ratings and their individual data sources are stored in the Atlas so that users can make their own risk assessment. The post-closure land use opportunities are meant to be reviewed and assessed by users of the Atlas as part of a bigger analytical process (i.e. the Atlas facilitates interpretation of data and information).

A web map was created with multiple iterations of the user interface, which were developed using ArcGIS Instant Apps (a platform that templates for developers to display georeferenced information) and ArcGIS Experience Builder (a platform that enables developers to create highly configurable web applications without requiring knowledge of computer programming/coding more flexible solution for developing web map applications such as the Atlas) (Esri, 2023). ArcGIS Experience Builder allows developers to embed web maps in a layout of their choice without restriction. Developers can also choose and configure numerous widgets that interact with the web map (e.g. a widget can be added for users to add their own data to the web map). ArcGIS Experience Builder allows developers to configure products to work on desktops/laptops, tablets, and smartphones. However, it does require users to access developed products through their internet browser.

The Beta 1.0 version of the Atlas was developed using ArcGIS Instant Apps 'Exhibit' template. The Beta 2.0 and current versions were developed using ArcGIS Experience Builder.

The Atlas was designed to be comprehensible by stakeholders with various backgrounds and co-development of software requires careful consideration of the intended users of the Atlas. Table 6.1 illustrates potential users of the Atlas by adapting the key stakeholders of mine closure planning identified by the ICMM (2019) to the South African context. Government officials could use it for policy, planning and budgeting – knowledge of potential mine closure and impacts on local economy and communities will help them to identifying areas requiring intervention or monitoring. Mining companies could use the knowledge of potential risks and vulnerabilities of communities and environment for planning and budgeting. Consulting companies could use the Atlas for the assessment of risks and opportunities for mining companies and government. Investors could use it for making investment decisions on mining companies and on post-closure developments. The mining workforce could use the knowledge of potential mine closure and estimated timeframes for personal career planning. NGOs could use the knowledge of potential risks and vulnerabilities of communities and environment to raise awareness and engage with mining companies and local government. Mining host communities and labour sending areas could use it for planning and engagement. Since all the data reproduced in the Atlas is open-source, users can download the data directly from the Atlas to be used in other databases. For example, consulting firms will be able to download data from the Atlas for development of their own databases.

The Beta 1.0 version was presented to the WRC project reference group to gauge expert opinion while the Beta 2.0 version was presented at an online stakeholder engagement workshop conducted by the Project Team in March 2023 via Zoom. Over 70 experts in the mining industry, consulting, academia, civil society, and government, were invited however only 15 attended on the day. The project team presented the draft mine closure risk framework and the Beta 2.0 version of the Atlas. The draft risk rating and the Atlas functionality were presented to the workshop participants before a live link to the Atlas was shared with them. Participants were given approximately 15 minutes to use the Atlas and were encouraged to explore mining regions that they are familiar with using the Atlas and the data contained within it. They were also encouraged to ask questions and comment on the Atlas while using it. Participants were then asked to complete a survey using Zoom's Advanced Poll functionality. Survey questions were divided into five themes – layout and experience; information; visualisation; distribution; and further resources and each theme comprised of one or two questions – a limit imposed by Zoom Advanced Polls. The stakeholder feedback was used to develop the Beta 3.0 version of the Atlas.

The Atlas was also the subject of a peer-reviewed conference paper publication and presentation at Mine Closure 2023 (see Esau et al., 2023) in Reno, Nevada, United States of America, attended by mine closure experts from across the world. The presentation of the Atlas was well received by the audience.

Table 6.1 Stakeholders considered as potential users of the Atlas

Stakeholder	Potential use of the Atlas	Scale of information	Frequency
National Government	Policy and planning	National	Annually
Provincial Government	Planning and budgeting	Regional	Annually
District Government	Planning and budgeting	Regional	Quarterly
Local Government	Planning and budgeting	Local	Quarterly
Mining Companies	Planning, risk assessments	Local/regional	Annually
Consulting Companies	Risk assessments and post-closure land use opportunities assessments	Local/regional	Daily
Investors	Investment decisions on mining and post closure developments	Regional/local	Monthly
NGOs	Raising awareness and engagement	Local	Monthly
Mining communities	Planning and engagement	Local	Ad hoc
Labour Sending Areas	Personal planning and engagement	Regional/local	Ad hoc
Traditional Authorities	Raising awareness and planning	Local	Ad hoc
Mine workforce	Career planning and employer engagement	Regional/local	Ad hoc
Labour unions	Engagement and negotiations with mine employers	Local	Ad hoc
Media	Raising awareness	All scales	Ad hoc
Researchers	Conduct research that informs mine closure policy and planning	All scales	Ad hoc

6.2.1 Datasets in the Atlas

The Atlas displays 44 national datasets and 16 global datasets obtained from multiple sources, together with the project team's own research (see Table 6.2). The primary datasets are the large-scale operating mines and mining host communities which have been developed over the past five years. Data included in the operating mines dataset covers commodity, company, life of mine, mining method, duration of mining, employees and the three risk ratings. A third of all operating mines are coal mines and over a quarter are platinum mines. The mines are hosted by very diverse communities, which include cities, mining towns, non-mining towns, townships, mine villages, informal settlements, and rural villages. They were home to almost 6.5 million people in 2011 and are situated in three metropolitan municipalities and 58 local municipalities that had a total population of 23.6 million in 2016. Data included in the community dataset covers main commodity, type of community, municipalities, area, population, households, population density, household size, gender, race, urban/rural, collective living quarters, industrial areas, formal housing, household income, household goods, health, education level, piped water access, electricity access, cooking fuel, refuse removal, employment, and internet access. All datasets in the Atlas can be overlayed on various base layers built into the Atlas, including base layers of satellite imagery, which assist the analyses of mine sites. Other base layers include topographic, terrain and open street maps.

Table 6.2 Datasets in the Atlas

Theme	Datasets	Data sources
Mines	Operating mines; Mine site boundaries and features; Tailings facilities; Processing plants	Cole & Broadhurst, 2021; Tang & Werner, 2023; Maus et al., 2022; Global Tailings Portal, 2023; DMRE, 2022
Communities	Mining communities; local municipalities; main places; sub places	Cole & Broadhurst, 2021; StatsSA Census Spatial Data
Administrative Boundaries	Provinces; District municipalities; Local municipalities; Farms; Former homelands	Municipal Demarcation Board Spatial Knowledge Hub
Water	Strategic Water Source Areas; Mean Annual Runoff; Mean Annual Rainfall; Mine Water Threat; Drinking water quality; Wastewater quality; Water stress; Rivers; Dams; Estuaries	SANBI Biodiversity GIS; DWS Spatial Data; WRC Mine Water Atlas; DWS Green Drop Report 2023, DWS Blue Drop Report 2023; Cole, et al., 2018;
Land	Land capability; Land cover; Morphology; Grazing Capacity	DAFF; South African DFFE GIS Data; Kruger 1983; SANBI Biodiversity GIS
Biodiversity	Ecosystem threat status; Protected areas; Conservation areas; Important Bird Areas; Mining and Biodiversity Guidelines; Protected Areas Expansion Strategy Focus Areas; National Freshwater Ecosystem Priority Areas	SANBI Biodiversity GIS; BirdLife South Africa
Energy	Power lines; Existing Power Plants (coal, solar, wind, nuclear, hydro); EIA Applications for Renewable Energy Development; Renewable Energy Development Zones; Strategic Transmission Corridors; Strategic Gas Pipeline Corridor; Solar energy potential; Wind energy potential	DFFE GIS Data; Global Energy Monitor; Wind Atlas for South Africa; Global Solar Atlas
Transport	Primary road; Secondary roads; Ports; Airports	SANRAL; World Port Source
Economy	GVA for mining and quarrying	CSIR 2018

6.2.2 Atlas functionality

The South African National Mine Closure Risk and Opportunity Atlas displays data pertaining to all operating mines in South Africa, South African mining host communities, host local municipalities and datasets related to mining, mine communities and post-closure development planning. Upon opening the Atlas, users are greeted by a splash page which welcomes them and provides a brief description of the Atlas, the data it contains, its purpose, and the target audience. The main map then appears with all mines displayed on a map of South Africa (Figure 6.1). A Layers panel on the right gives the user access to all the datasets which are categorised under nine headings – Operating Mines, Mining Host Communities, Administrative Boundaries, Land, Water, Biodiversity, Energy, Transport and Economy. Each category has a dropdown list of all the relevant datasets which can be displayed on the main map and toggled on or off as required. A ‘Details’ page is linked to every dataset, which opens in a new tab and provides a brief overview of the dataset and a direct link to its source. A Legend panel on the left shows the legends for the current active layers. The default display is of mines colour-coded by their likelihood of closure risk rating (Figure 6.1), but other legends (e.g. commodity, social impact of closure risk rating, environmental impacts of closure risk rating) can be shown.

Discrete data pertaining to individual mining host communities and mines can be accessed by selecting the mining host community or mine of interest from the map and are presented using pop-ups (Figure 6.2). Built-in interactive tools allow users to search for a particular location on the map by typing in key words or the name, zoom in or out, toggle spatial layers on or off, and change the base map. Widgets have been added to the Atlas to enable users to draw graphics, add their own data, do specific location analysis (Figure 6.3) and elevation analysis (Figure 6.4), and capture and download static maps as described in Table 6.3. While the Atlas works best on a desktop or laptop, it has also been calibrated to work on smartphones and tablets and can be accessed by users through a browser on their device. When using the Atlas on a tablet or smartphone, navigation is not as sophisticated as when used on a desktop or laptop as some functions may not work, however all the same datasets are present.

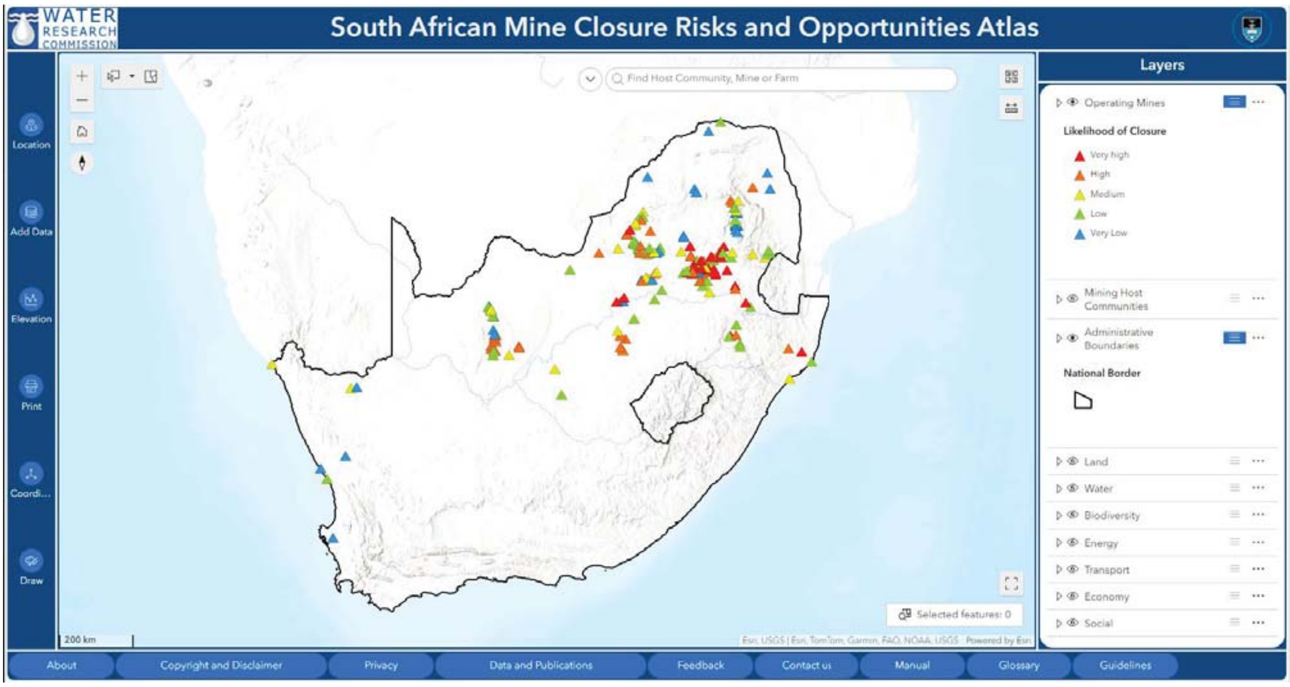


Figure 6.1 Screenshot of the default page for the South African Mine Closure Risk and Opportunity Atlas which displays the mines (triangles) coloured by likelihood of closure rating

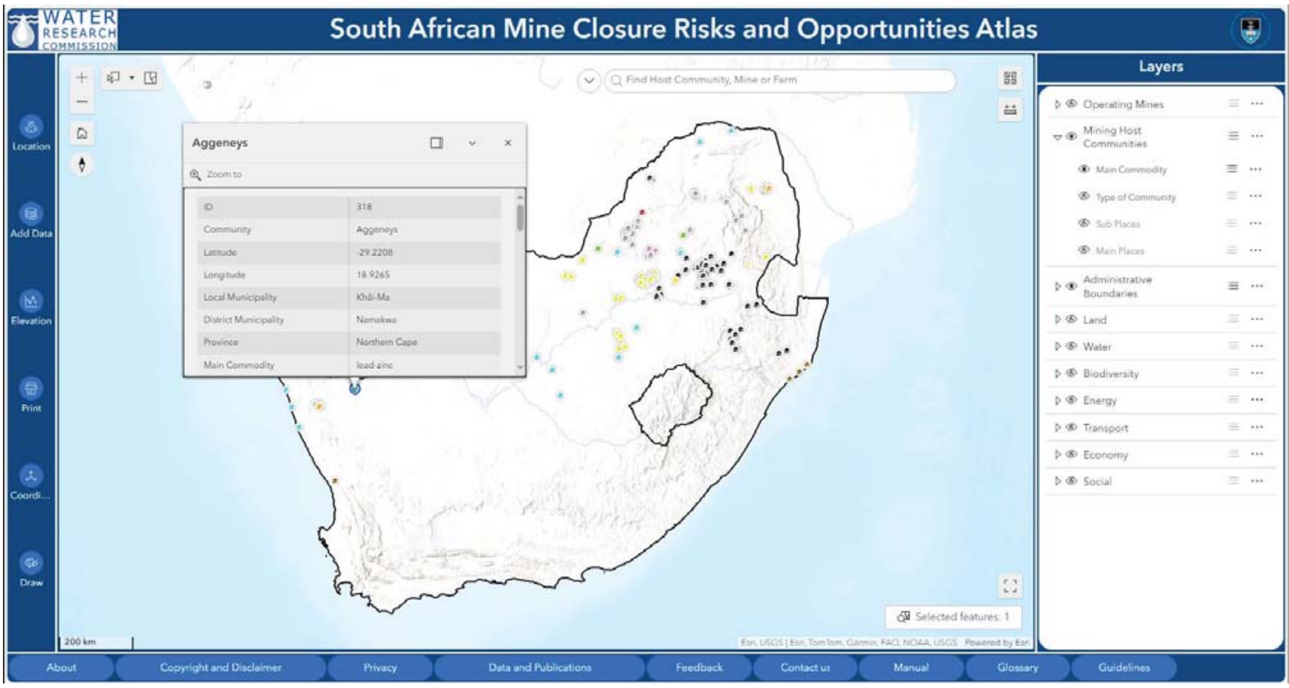


Figure 6.2 Screenshot of mining community assessment in the Atlas

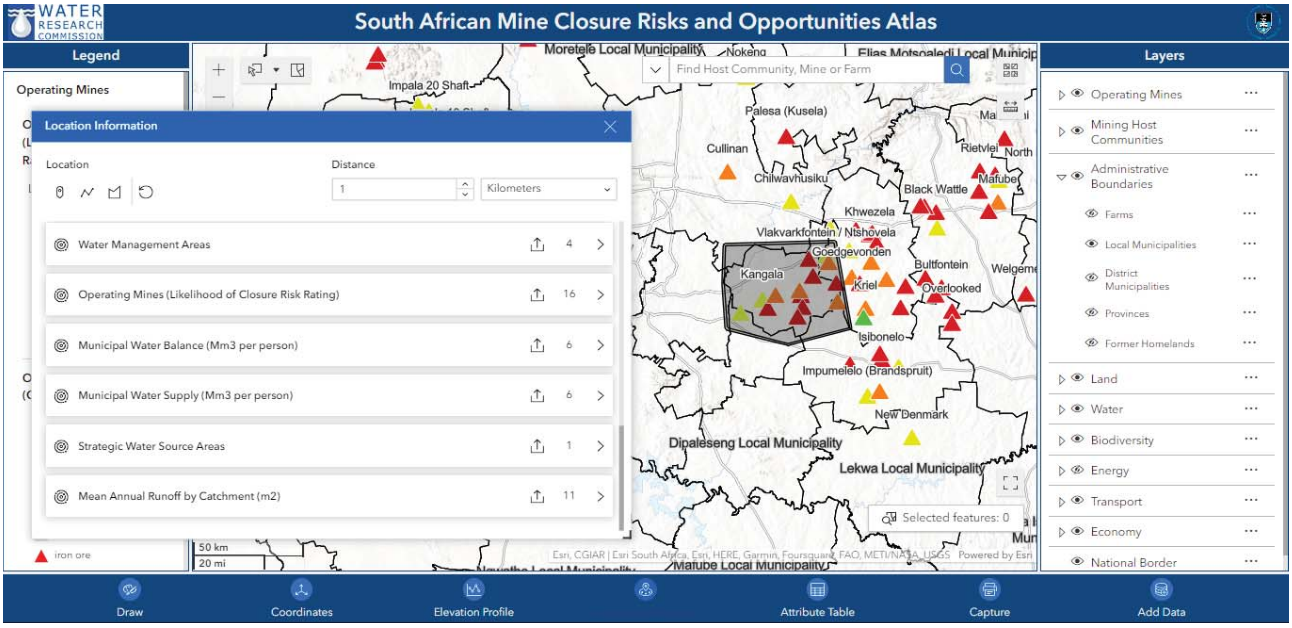


Figure 6.3 Screenshot of location analysis in the Atlas

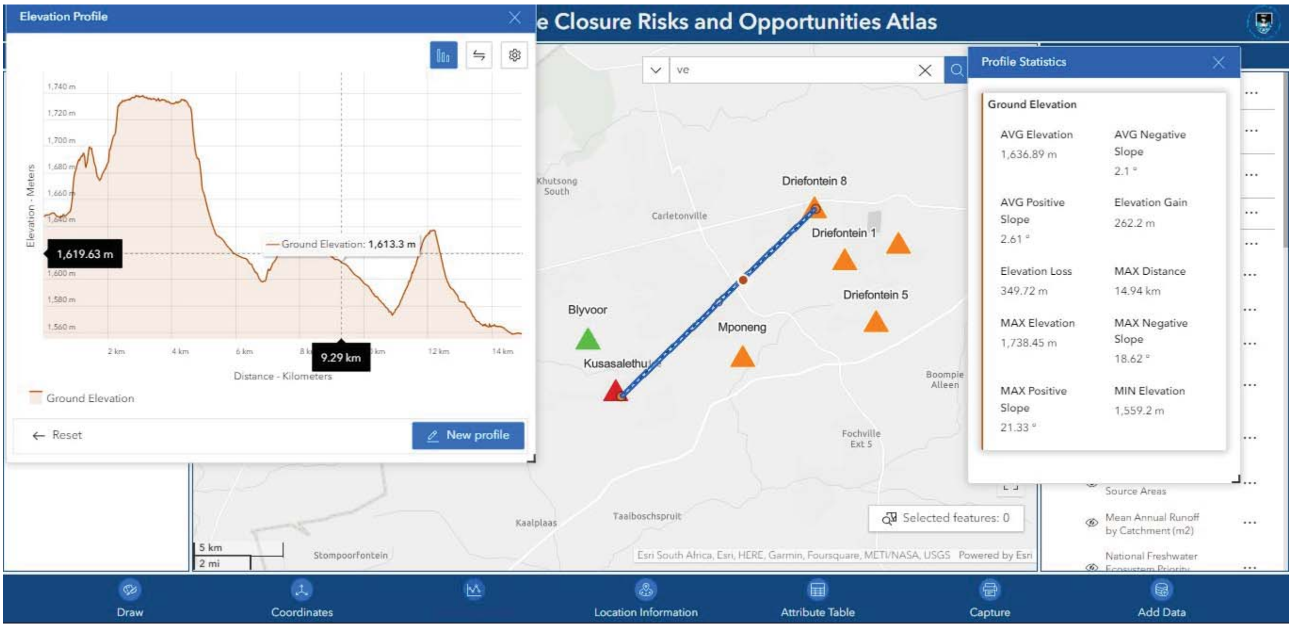


Figure 6.4 Screenshots of elevation analyses in the Atlas

Table 6.3 Widgets contained in the Atlas and their function

Widget	Function
Web Map	Contains all the data. Users can select features to display more information about them by clicking (laptop/desktop) or tapping (tablet or smartphone) on them. Contains orientation button, default view button (zooms to a default view of South Africa), zoom in/out buttons, base map button (choose between base maps), search button, measure button (measure distances and areas on web map), and a full screen button.
Legend Panel	Defines features displayed on the web map.
Layers Panel	Lists all data in the web map grouped by theme. Groups can be expanded using the 'expand' arrow on the left of each group. Layers can be hidden or unhidden using the 'eye' icon next to the 'expand' icon. Three horizontal dots on the right of each layer allows users to increase or decrease the transparency of the layer and provides a link to a 'Details' page with metadata.
Draw	Allows users to create simple graphics for points, lines, and polygons on the web map.
Elevation Profile	Generates and displays an elevation profile based on a path created by drawing lines on the web map. Slope and elevation statistics can be viewed.
Attribute Table	Displays the database used to create the web map in tabular format. Layers to be displayed can be selected from the drop-down menu. Features can be selected and filtered using the 'show/hide' icon. Attribute tables can be downloaded in csv format.
Capture	Allows users to create static maps of the map extent displayed when the capture widget is selected. A legend, north arrow, and scale bar can be added in 'advanced' options.
Add Data	Adds data sources to the Atlas at run time via ArcGIS content, URL, or local storage (shapefile, csv, or GeoJSON formats).
Location analysis	User can select an area of interest and interrogate datasets for that area

6.2.3 Expert input

Based on the responses to the questions posed at the online multi-stakeholder engagement workshop, it can be assumed that the audience was satisfied with the overall layout and functionality of the Atlas. No issues were raised regarding the format of the visualisations or the tools available for use within the Atlas. However, questions were raised pertaining to the information hosted in the Atlas. In broad terms, these mainly pertain to the lack of mine site information regarding mine closure. However, it was noted that this information may be difficult to obtain (from the DMRE and mining companies). Furthermore, the audience emphasised that more expert input is needed to fully develop the Atlas and incorporate this information. The research group were aware of this aspect and conducted individual interviews with relevant experts in the following phases of the research programme (audience members from this workshop also partook in these interviews). The stakeholders provided valuable information regarding the distribution of the Atlas and further resources that will be of use for its further development.

Five semi-structured interviews were conducted with experts in the consulting, governmental, academic and renewable energy industries. The interviewees were given a chance to use the Atlas and were asked to assess the datasets and the analytical tools. The interviewees raised valuable suggestions for improvement. In terms of layout and experience, feedback was mixed, with some interviewees finding the Atlas user-friendly, while others experienced challenges with navigating the Atlas and discovered features only after some exploration. Recommendations included the addition of a tutorial in the form of a video or instruction manual and better widget categorisation. Additionally, interviewees highlighted visibility issues with map feature labels and suggested highlighting selected map features in the attribute table to enhance user experience.

Interviewees praised the Atlas for its depth and richness of data, particularly for environmental reports and understanding cumulative impacts of mining operations. Interviewees expressed their need for additional data related to land and mining rights, socio-economic factors, and links to SLPs. While interviewees had a positive overall impression of the Atlas and recognised its utility, there was a need to clarify its role as a decision-making aid rather than a definitive source of answers. The comments and concerns raised by stakeholders were evaluated and those that could be actioned, were addressed in the final version of the Atlas. The requests for additional datasets, such as SLPs for all mines in South Africa, is a large undertaking and beyond the scope of the project.

6.3 Application of the Atlas

6.3.1 Value of a GIS-based mine closure atlas for the mining sector

The Mine Closure Atlas was designed to facilitate mine closure risk assessment and post-closure land use development planning related to the South African mining industry. Although stakeholders have access to much of the information contained in the Atlas, they may not be aware of it, and there is no single platform that integrates the diverse datasets and makes them easily accessible. The comprehensive array of datasets in the Atlas adds value to the mining sector by providing access to information from a centralised node connected to segregated information sources. Additionally, the Atlas facilitates advanced analyses, such as plotting elevation profiles, from within the Atlas without requiring the downloading of specialised software.

The Atlas displays mining, social, economic, environmental, governance and demographic datasets that are relevant to mine closure. The intention of the Atlas is threefold: 1) to make data and information of mines and mining communities and their associated risks and opportunities publicly available to all stakeholders, 2) to provide a visual comparison of likelihood of mine closure, socio-economic risk and environmental risks for all operating mines, and 3) to provide an analytical tool to assess mine closure risks and post-closure land use opportunities by making multiple relevant spatial datasets accessible and user-friendly. These aspects support mine closure planning and aid decision-making processes at all scales. While the Atlas offers a preliminary risk rating for each mine site, the underlying data is also included so that the user can make their own assessment. The post-closure land use opportunities are meant to be reviewed and assessed by users of the Atlas as part of a bigger analytical process. Analyses such as environmental risk analyses using a GIS database – as illustrated by Werner (2019) who conducted a preliminary comparative environmental risk analyses on four abandoned mines in Australia using satellite imagery and geospatial information – is intended to be conducted by users of the Atlas rather than the Atlas presenting a set of answers. The Atlas is presented as a facilitator for such analyses.

The environmental, social, economic, infrastructural and governance datasets presented in the Atlas support evidence-based decision-making on post-closure land use by bringing together diverse spatial datasets together with mine site information. For example, the potential for agriculture can be assessed with the water supply, land cover, land capability and grazing capacity datasets before this is put forward as an option; solar potential, wind potential and electricity transmission lines datasets can be reviewed together before renewable energy generation is proposed; and water stress, local education levels, governance metrics and road networks can be reviewed together when considering starting new industries.

Although visualising the characteristics of a region in cartographic form using GIS creates an oversimplified depiction of reality, analysing a region in spatial and visual terms sanctions wider public debates and supports communities impacted by mining who are least represented (Werner et al., 2019). Making information about mine closure risks and opportunities accessible to mining host communities, particularly through the Atlas being supported on smartphones, empowers them to engage in and influence decision-making processes.

Showing the evidence for socio-economic deprivation in mining host communities to mining companies gives them the understanding and motivation to do more to support these communities when mine closure occurs. This is effective use of GIS in the context of socio-economic dynamics – empowering the least represented to participate in decision-making processes (ibid).

6.3.2 Data challenges and opportunities

Datasets contained in the Atlas were collected during 2022 and 2023. While every effort has been made to incorporate the most recent and up to date data, the Atlas will require updates over time as new mines open and existing mines close, existing datasets are updated and new datasets are released. This requires an ArcGIS licence and a person or team who stays abreast of developments. The Atlas currently presents a snapshot of information although it has an 'Add Data' function, which allows users to insert their own spatial data into the Atlas and combine it with the other datasets. In future additional functionality could be added to display time series data for certain datasets. While the maintenance of the Atlas could be seen as the responsibility of the national government, current failures in maintaining other datasets and platforms (e.g. the national mining cadastral system) make this unviable at this time.

While there are many national open-source datasets available online that are useful for assessing mine closure risks and post-closure land use opportunities, some are not often updated. One example is the community-level socio-economic data obtained from the national census which is undertaken once every 10 years. StatsSA performs the household surveys but is financially constrained; however, the mining industry could provide financial support and benefit from a better understanding of their host communities.

It would be very useful to have local mine site technical information. Most mining companies report environmental data (such as water use) at the corporate level, aggregating all mine sites for a region, country or company. Mine site expansions are not generally publicised until they have been through the required environmental impact assessments and approvals and as such cannot be independently assessed by civil society and communities who will be most affected. Several stakeholders emphasised the need for mine site information but agreed that this is difficult to obtain as mining companies are not required to make the data publicly available and they typically do not want to release data without it being interpreted. The national DMRE is the responsible authority which facilitates the sharing of this information, however, they often fail to do so.

Additional datasets that would be helpful in assessing mine closure impacts and planning for closure include financial provisions; current land ownership and zoning; land claims by traditional authorities and dispossessed people; historical land use, historical mine design and site configuration including underground mine maps to understand the impact on water resources, and surface maps to assess site human and ecological risks.

6.3.3 Data access and interpretation

In addition to issues of internet access in South African mining host communities, awareness of the Atlas and the data it contains is a key factor in mining host community participation in decision-making processes regarding mine closure planning. Stakeholders suggested several solutions for awareness creation within local communities. While all these solutions are viable, they all require third party endorsement. Since the data contained within the Atlas can potentially be interpreted as detrimental towards the perception of certain mining companies, they may be hesitant to make their stakeholders aware of it. Therefore, a third party that is concerned with the wellbeing of the environment and society without financial influence is best suited to facilitate awareness campaigns for the Atlas. This includes governments and NGOs, who can assist in awareness creation of the Atlas at local community meetings, local economic forums and community forums, schools, and sharing the Atlas on social media. NGOs and other organisations may host training sessions on the Atlas.

Once stakeholders are aware of the Atlas, it is imperative that they are educated on how to interpret the data contained in the Atlas. The Atlas was designed with a simple user interfaced that does not require any specialised training to use. However, the low levels of education among South African mining host communities (Cole & Broadhurst, 2021) may pose an obstacle to these stakeholders. While interpretation is a subjective exercise, understanding the implications and nature of data in the first instance is the first critical step in the process of interpretation. The Atlas provides metadata and details about each dataset it contains via the Details page to support this, however, it is difficult to determine the level of understanding and interpretation of the data by potential users. Some responsibility lies with mining companies to translate complexity into simple easy to understand language for their affected parties to understand when dealing with mine closure. While that takes time and resources, it could have significant benefits of positive stakeholder relations and a higher likelihood of success of post closure initiatives.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

This report has described four case studies and the development of three novel tools for South Africa to inform a wide range of stakeholders about mine closure risk and opportunities and support their assessment: a mine closure risk rating system, a post-closure land use opportunities framework and an online Mine Closure Atlas. The mine closure risk rating system identifies mines and areas where mine closure is highly likely and needs immediate attention. It also ranks mines by considering social risk and environmental risks potentially resulting from closure, enabling the prioritisation of mitigation and intervention by mining companies and government. The post-closure land use framework provides a process for identifying the most suitable options based on participatory process that involves reviewing all possible alternatives, identifying influencing factors, and quantifying suitability indicators. Supporting the risk rating system and the land use opportunities framework is a comprehensive spatial database covering mines, processing plants, mining communities, land, water, energy, biodiversity, infrastructure and governance. Future research could see the expansion of the datasets incorporated into the three tools, and possibly language translation for more South African official languages. Ideally the Atlas would be regularly updated as the underlying global and national datasets are updated.

The tools are aimed at supporting and informing a wide range of stakeholders, with particular effort given to ensuring mining community members can access information about their nearby mine. The functionality of the Atlas on all types of devices empowers the most vulnerable in society who often do not have a voice in post-closure discussions. It is hoped that this will support just transitions away from mining in different regions across the country. In addition, the Atlas could promote deeper discussions on mine closure management and planning amongst a diverse group of stakeholders, and support evidence-based decision-making. Finally, while the three tools have been developed for South Africa, the concepts, design and insights could be applied to any mining country in the world.

7.1 Case studies

The learnings from the various case studies provide insight into current and emerging mine closure and post-mining land use approaches, the opportunities, challenges and influencing factors across social contexts, regions and different stages of life of mine. The COP project highlights the opportunity to use industrial crops for both rehabilitation and the creation of downstream industries due to their ability to form multi-products from fibre and phytoremediation potential. The Bokamoso Ba Rona project shows a multi-stakeholder collaborative approach for using mine-impacted land to create large scale regenerative agricultural projects which include crops and livestock. The Green Engine case study presents an approach that integrates post-mining land use, agriculture water treatment, waste management and industrial development but faces challenges due to vandalism and illegal mining. The Impact Catalyst project provides lessons on early-stage project development for an operation with a significant life of mine, that has looked at integrated game farming, agriculture, and agro-processing development initiatives to align with the rehabilitation plan of the mine.

Learnings across the projects highlighted the importance of considering numerous social, economic and environmental influencing factors in planning for mine closure and post-mining land use development. There are several common land use opportunities across the projects including agriculture, agro-processing, livestock, game farming. However, the options around agriculture and crop selection and the potential to develop downstream agro-processing value chains need to be further understood. Other key opportunities that have emerged are around water treatment, renewable energy projects and the potential for energy provision post-closure, but there is a need to understand other opportunities around housing, tourism, and heritage sites.

Despite the various identified opportunities and increasing effort to consider more holistic regenerative post-mining development initiatives, there continues to be a lack of integration in social development initiatives, rehabilitation and post-mining development, which continues to pose a risk to long-term regional development beyond mining activity. There also continues to be uncertainty on the continuity of projects when assets are bought by another company, which often happens when mines near their end of life.

7.2 Mine closure risk maps

The map of likelihood of mine closure showed that the high risk of closure in the Mpumalanga coal fields, the majority of gold mines in Gauteng, Free State and North West provinces, and a few chromium and platinum mines in the North West province. The mines with the highest social risk ratings are almost all platinum and chromium mines in North West and Limpopo provinces, as they are surrounded by deprived rural villages and have very large workforces. Notable exceptions are the copper and phosphate mines in Phalaborwa, which are two of the most remote mines, and two coal mines in eastern KwaZulu Natal, which all have deprived rural communities. The manganese mines in Northern Cape have a high risk rating due to their deprived rural communities and remote location. Although most gold mines have large workforces, their communities are better off with lower dependency ratios, and they are close to cities. Similarly, the remaining of coal mines have lower social risk because they are hosted by small towns near cities, with higher levels of wellbeing and lower dependency and their workforce is relatively small compared to gold and platinum.

7.3 Recommendations

Main recommendations from the project are:

- While four case studies have given useful insights into the types of post-closure land use approaches currently being taken in South Africa, further research is required into the longer-term impacts and outcomes of land use transition away from mining in the country and globally. For example, analysis on the closure of coal mines in the 1980s in KwaZulu-Natal leading to the exploration and development of alternative economic activities such as tourism would be very informative.
- The risk ratings proposed here are a first attempt at a national comparison of likelihood of mine closure, social risk and environmental risk, and will require further testing and analysis in the future. Additional datasets will be required to fill gaps and ensure the risk rating captures all the influencing factors. As social, environmental and governance aspects of mine closure are intertwined, the weightings need to be reviewed, and the local contexts must be considered. The weighting of factors may differ across local contexts and therefore critical engagement by mine closure stakeholders with the risk ratings is essential.
- The likelihood of closure risk map has highlighted the mines at highest risk of closure, and provincial, district and local government should take note of how this may affect their planning and budgeting in the short and medium term. National government could use the national risk maps to focus their interventions and programmes to alleviate the negative impacts of closure.
- The post-closure land use framework should be applied to mines that are likely to close in the next few years to ensure that all possible alternative have been considered, and that the current aims and objectives of existing mine closure plans are supported by a wide group of stakeholders.
- There three tools developed in this project could be used in developing Mine Closure Plans, undertaking Environmental Risk Assessments and assessing financial provisions for rehabilitation of negative environmental impacts, all required by mining companies in South Africa under Regulation

11 (1) of Government Notice R1147. It can also be used by Future Forums designated in Social and Labour Plans for engaging host communities in mine closure planning, in the development of Integrated Development Plans by local municipalities, and in regional spatial planning by district municipalities and provincial governments. Finally, it could play a supporting role in the implementation of the National Mine Closure Strategy by the DMRE.

- As identified in the post-closure land use framework, mine closure decision-making tools should be used in conjunction with efforts to build relations in or among communities potentially impacted by mine-closure and time should be given to the participatory process to ensure as wide an input as possible.

Several areas of future research were identified during the project. These include

- the development of a spatial database of mines that are on care and maintenance, closed or have been abandoned,
- making the links of the mine closure risks and opportunities to the broader Just Transition agenda in South Africa,
- considering mine closure policy in relation to Artisanal and Small Scale Mining (ASM),
- consideration of which mining areas have development programmes and which do not, and therefore require additional support for mine closure,
- assessment of the timeframes around mine closure given project lead times and long-term implications in contrast to the short-term benefits that stakeholders may expect,
- the preparedness of individual mines to close in terms of financial provisions, mine closure plans, and engagement with the affected communities,
- a framework or approach to measuring the cumulative impacts of mine closure, rather than the individual social, economic or environmental impacts, and
- analysis of governance as a critical mechanism to implement the tools developed by the research project.

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APPENDIX A

Stakeholder interviews

Thirty semi-structured interviews were conducted with experts across mining companies, industry bodies, research and academia, consultants in mine closure and post-mining development, community support organisations, as well as policy and legal experts. The interviews were conducted over 2021 to 2023 to gain insights on key case studies and the broader landscape of mine closure and post-closure opportunities in South Africa.

Stakeholder	Stakeholder Category	Interview Dates
1	Industry body	10/03/2021
2	Industry body	18/03/2021
3	Consultant	23/03/2021
4	Consultant	14/04/2021
5	Community Support	15/04/2021
6	Academia and Research	19/04/2021
7	Consultant	05/05/2021
8	Consultant	18/05/2021
9	Consultant	10/05/2021
10	Academia and Research	12/05/2021
11	Government	17/05/2021
12	Policy and legal	18/05/2021
13	Community Support	11/06/2021
14	Government	14/07/2021
15	Mining Executive	26/07/2021
16	Industry body	16/08/2021

17	Community Support	28/09/2021
18	Community Support	15/10/2021
19	Academia and Research	25/02/2022
20	Policy and legal	01/03/2022
21	Consultant	16/06/2022
22	Policy and legal	29/03/2022
23	Mining Executive	04/04/2022
24	Policy and legal	13/04/2022
25	Mining Executive	09/05/2022
26	Consultant	07/2023
27	Local government	08/2023
28	Donor agency	08/2023
29	Multi-lateral agency	09/2023
30	Consultant	09/2023

Case Study workshops

Insights were obtained through 11 workshops that were attended to support the evaluation of the case studies' contexts, opportunities, barriers and challenges.

Workshop Description	Organisation	Date	Case Study	Stakeholder Groups Present
Post-Mining Transformation through the Fibrous Plant Economy	DPRU, CeBER, MLiA, Minerals to Metals (UCT)	28 May 18	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies (DPME, DTI, ARC, Minerals Council), Mining Executives
Sibanye-Stillwater Bokamoso Ba Rona Project Brief	Sibanye-Stillwater	25 Oct 18	Case Study 2	Mining Executives, Government, Consultants, Policy & Legal

Developing a Fibre Micro-industry to Generate Economic Growth from Degraded Land Post-Mining	DPRU, CeBER, MLiA, Minerals to Metals (UCT)	17 Oct 19	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Legal and Policy
The Green Engine Driving Life After Coal	Anglo American	24 May 19	Case Study 3	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Community Support Groups
Driving Post-mining Industrial Development through Fibrous Multi-product Value Chains	DPRU, CeBER, MLiA, Minerals to Metals (UCT)	24 May 19	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Legal and Policy
Fibrous Futures: Resilience & Realism: Analysing the legal and economic complexities	DPRU, CeBER, MLiA, Minerals to Metals (UCT)	30 Julm19	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Legal and Policy
Sustainable Mine Closure and Life Beyond The Mine: Building Resilience and Growing Change.	Minerals to Metals, SAIMM	16 Sep 20	Case Study 1 & 3	Research & Academia, Industry Bodies (Mine Water Coordinating Body, Impact Catalyst), Policy and Legal, Consultants
Impact Catalyst expanding the Network	Impact Catalyst, Zutari	22 Jan 21	Case Study 4	Research & Academia, Industry Body, Policy and Legal, Consultants , Government
Industrial Opportunities in Mining Areas: Technical, Economic, and Regulatory Considerations	DPRU, CeBER, MLiA, Minerals to Metals (University of Cape Town)	25 Nov 21	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Legal and Policy
Re-Imagining Post-Coal Futures for a Local Green Energy Transition	DPRU, CeBER, MLiA, Minerals to Metals (University of Cape Town)	07 Nov 22	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies, Mining Executives, Legal and Policy
Using a Multi-Disciplinary Approach to Explore Opportunities for Economic Diversification in Mining-Intensive Jurisdictions	DPRU, CeBER, MLiA, Minerals to Metals (University of Cape Town)	10 Feb 23	Case Study 1	Research and Academia, Consultants (Mine Closure, Environment), Industry Bodies (DPME, DTI), Mining Executives, Legal and Policy

Participant observation dialogues

Insights on the broader mine closure landscape in South Africa and post-closure opportunities were gained through 17 participant observation dialogues over 2018 to 2023 as shown in the table below. These dialogues were across key themes, mainly mine closure challenges, community perspectives, post-closure opportunities, policy and regulatory frameworks and just transitions. Through participant observation researchers were able to either actively participate in dialogues, act as silent observers especially to glean into stakeholder dynamics and form independent perspectives of key themes. The strength of this approach is in promoting for a more in-depth understanding of patterns, dynamics and conflicts in complex sustainability challenges.

Dialogue description	Organisation	Date	Themes	Stakeholders present
Bench Marks Foundation Conference	Bench Marks Foundation	22 Oct 18	Community perspectives	Community Support Groups (Bench Marks Foundation), Research & Academia, Policy and Legal (FSE, Advocacy Groups), Mining Executives, Industry Body (Minerals Council)
Mining Diversification workshop	CSIR	28 Aug 18	Post-closure opportunities	Research and Academia, Consultants
Mine Closure and Case Law Workshop	Imbewu	20 Jun 19	Policy	Policy and Legal (Law Firms, Advocacy), Research and Academia
Mine closure and rehabilitation in South Africa	Mining Dialogues 360	31 Jan 20	Mine closure, Rehabilitation	Community Support Groups (Mining Dialogues), Industry Body, Government (DMRE, DFFE), Research and Academia
Advancing the Just Transition	Minerals Council	20 Oct 20	Post-closure opportunities	Industry Body (Minerals Council), Mining Executives, Government, Policy and Legal, Research & Academia, Consultants
Mpumalanga Green Economy Opportunities – Life After Coal	Green Cape	11 Feb 21	Post-closure opportunities	Research & Academia, Industry Body, Policy and Legal, Consultants , Government
Unravelling South Africa's Just Transition: Unpacking sectoral interventions for Mpumalanga	TIPS	24 Mar 21	Post-closure opportunities	Research & Academia, Industry Body, Policy and Legal, Consultants , Government
Economic succession planning – Part 1	Minerals to Metals, SAIMM	19 May 21	Mine closure planning, Post-closure opportunities	Research & Academia, Industry Body, Policy and Legal, Consultants, Government

Mine Closure National Policy – Part 2	Minerals to Metals, SAIMM	14 Jul 21	Policy	Government (DMRE), Industry Body (Minerals Council, Council for Geoscience, Mine Water Coordinating Body, Impact Catalyst), Policy and Legal (Law Firms, FSE and Advocacy Groups), Community Support Groups (Lesetlheng Land Committee), Research & Academia, Consultants and Mining Executives
Mine Closure National Policy – Part 3	Minerals to Metals, SAIMM		Policy	Government (DMRE), Industry Body (Minerals Council, Council for Geoscience, Mine Water Coordinating Body, Impact Catalyst), Policy and Legal (Law Firms, FSE and Advocacy Groups), Community Support Groups (Lesetlheng Land Committee), Research & Academia, Consultants (Climate Change, Just Transitions, Mine Closure) and Mining Executives
Webber Wentzel – mining round up and policy	Webber Wentzel	03 Mar 22	Policy	Policy and Legal (Law Firms), Mining Executives, Consultants (Environmental, Mine Closure), Research & Academia
National Mine Closure Strategy Consultation	IAIAA	15 Mar 22	Policy	Consultants (Environmental, Mine Closure), Policy and Legal (Law Firms, Advocacy Groups), Mining Executives and Research & Academia
Voices Under a dark cloud	TIPS	27 Jun 22	Community perspectives	Community Support Groups (Ground Works, National Labour and Economic Development Institute), Research & Academia (TIPS), Consultants (Climate Change, Mine Closure)
Bench Marks AGM on mine closure	Bench Marks Foundation	18 Oct 22	Mine closure challenges, Community perspectives	Community Support Groups (Bench Marks Foundation), Research & Academia, Policy and Legal (FSE, Advocacy Groups)
The pace of coal closures	Presidential Climate Commission	27 Oct 22	Mine closure, Just transitions	Government (Presidential Climate Commission), Industry and Industry Body (Minerals Council, Eskom), Community Support Groups and Civil Society (WWF), Research & Academia, Consultants (Climate Change, Just Transitions, Mine Closure) and Mining Executives
Alternative Mining Indaba 2023	Alternative Mining Indaba	7-9 Feb 23	Mining communities, just transition, mine closure	Civil society, research and academia, consultants,

Raising Standards for Mining -Experiences Using IRMA	IRMA	9 Feb 2023	Responsible mining	Civil society, research and academia, consultants, industry, government