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Derelict and ownerless mine sites in South Africa: history, legislation and a review of their management

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Abstract

South Africa has a long history of legacy mines that were operated with little environmental awareness for much of the 19th and 20th centuries. The legal owners of these legacy mines are often either deceased or no longer traceable, or, in the case of companies, have ceased to exist. As a result, the state has inherited the environmental liabilities of some of these mines, which are commonly referred to as derelict and ownerless (D&O) mine sites. The paper reviews the history and legislation surrounding D&O mines and proposes a revised management approach based on experience to date.

Early mining legislation in South Africa only focused on administrative processes such as issuing mining rights and collecting royalties and taxes, with environmental provisions being general in nature. The promulgation of the Minerals Act in 1991, the Mineral and Petroleum Resources Development Act (MPRDA) in 2002 and the National Environmental Management Act (NEMA) in 1998, followed by the implementation of the One Environmental System in 2014, introduced a more structured approach to sustainable mine closure in South Africa.

Subsequently, the state initiated a national D&O rehabilitation program to address environmental, health and safety challenges associated with these mine sites. Moreover, a database containing records of these D&O mine sites has been created and is continuously updated. However, to maximise the impact of the rehabilitation program, a systematic review aiming to manage D&O mines was undertaken. It highlighted a need for a revised approach to (i) estimate the state's envisaged financial liability for these D&O mines, (ii) manage latent impacts, especially in the areas of interconnection, by collaborating with other role-players in mine closure areas to meet end land use objectives; and (iii) identifying opportunities for repurposing at selected D&O mine sites to accelerate environmental and socio-economic benefits.

Keywords: *derelict and ownerless mines, envisaged financial liability, interconnection, repurposing*

1 Introduction

Modern mining in South Africa began as early as the 19th century, accelerated by the discovery of diamonds in the central part of the country and gold in the Barberton Greenstone Belt and the massive Witwatersrand gold deposits, followed by the exploitation of other mineral resources. South Africa's economy has

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significantly benefited from the exploitation of these mineral resources, creating employment and growth. However, mining has a substantial negative environmental footprint, especially if mine closure is not planned and managed from the early stages of mining.

South African mining legislation has evolved over time, and during the early part of mining, environmental consciousness was limited and the legislation was not explicit enough to guide mines to rehabilitate the impacted land and its surroundings. The early legislation (Republic of South Africa 1956) primarily focused on the administration of mineral rights and permissions (now referred to as old order rights), royalties and taxes generated by mining. As a result, mines were able to relinquish their mining rights without having to rehabilitate the land and did little to address environmental and safety concerns. Some of these mines have left large open pits, tailings and waste rock dumps without securing the surroundings for the safety of the communities. In some instances, these mines are interconnected, as in the case of Witwatersrand gold mines, leading to cumulative environmental impacts. In many cases the environmental impacts of historic mining are felt regionally, exacerbating the current socio-economic challenges that are being faced by communities. Often the mineral right holder of these mines is deceased or cannot be traced. In South Africa, these legacy mines are known as derelict and ownerless (D&O) mines.

The promulgation of the *Minerals Act* (Republic of South Africa 1991), the *Minerals and Petroleum Development Act* (MPRDA) (Republic of South Africa 2002) and the *National Environmental Management Act* (NEMA) (Republic of South Africa 1998a), followed by the One Environmental System in 2014, introduced and/or tightened legal requirements for environmental rehabilitation. The provision for financial guarantees to restore the land to a condition as close as possible to its original state or for the purposes of future development was introduced with the Minerals Act, improved with the MPRDA and is now defined in terms of NEMA, with clearly defined regulatory requirements for planning, implementation and reporting.

Considering the risk posed by D&O mines, the state has rehabilitated some of them to maintain the health and safety of surrounding communities. So far, approximately 400 unsafe mine openings and 45 asbestos mines have been rehabilitated by the state. These rehabilitation works have placed a substantial strain on the fiscus, which has prompted the team to explore options for the optimum utilisation of state resources. Moreover, the management of D&O mines should align with the principles of the draft National Mine Closure Strategy (NMCS). It is for these reasons that a review of the management of D&O mines in South Africa was undertaken and discussed in this paper for consideration. It must be noted that all the recommendations presented in this paper are preliminary, still under review and not final.

2 Status of derelict and ownerless mines and the database

South Africa has a large inventory of D&O mines that pose complex, spatially variable risks to both public safety and the environment (Cole et al. 2023). The Department of Mineral and Petroleum Resources (DMPR) reports 6,100 D&O mine entries derived from a consolidated national database maintained by the Council for Geoscience (CGS). This database integrated historical records from the Council for Scientific and Industrial Research and the South African Mineral Deposits Database (SAMINDABA), which contained records of previously mined mineral deposits that operated under different legal frameworks, with limited documentation on their operational status and environmental conditions. To address these gaps, systematic field investigations were conducted, enabling the classification of all 6,100 mine sites according to their operational status and inherent risk. This exercise resulted in the classification of 1,024 mines as operational (mineral rights could have been issued after the consolidation of the database, as the parent databases were static), while 5,076 were classified as non-operational and considered as D&O mines.

These D&O mines were subsequently prioritised for rehabilitation using a qualitative risk-based framework that primarily considered physical hazards and proximity to nearby settlements. In addition, environmental factors including acid mine drainage (AMD), water contamination, ecosystem degradation, the presence of sensitive receptors, pollution potential, site accessibility and the likelihood for illegal mining activities, where applicable, were given limited consideration for risk profiling. Sites were assigned a qualitative risk rating (e.g. low, medium or high) based on the likelihood and severity of adverse impacts. Although environmental

factors that refer to latent impacts such as the presence of AMD were given attention, these factors should be part of next phase of risk profiling as they impact long-term closure planning. Based on these criteria, the current risk status of the D&O mines in the database is as follows: 191 sites were ranked as high priority, 184 as moderate, 380 as low and 2,910 were ranked as requiring no immediate rehabilitation. A further 1,363 sites were recorded as visited, but no access due to access constraints during surveys, meaning they could not be classified; the remainder (48 mine sites) have been rehabilitated by the DMPR and the private sector. In addition to these mine sites, 1,215 hazardous mine openings were identified and ranked separately, forming part of the broader D&O mine inventory but excluded from the 6,100 recorded sites. Some of these D&O mines, as in the case of asbestos mines, pose environmental challenges. In response, the DMPR has adopted a phased rehabilitation approach. To date, approximately 45 legacy asbestos mines have been rehabilitated (Figure 1), and over 400 hazardous openings sealed (Figure 2) by the DMPR. Despite this progress, the state's envisaged rehabilitation liability remains significant.

(a) (b)

Figure 1 Asbestos mine in South Africa. (a) Before rehabilitation; (b) After rehabilitation

(a) (b)

Figure 2 Mine shaft. (a) Before closure; (b) After closure. Witwatersrand Basin, South Africa

Limited funding has necessitated prioritisation, particularly for asbestos rehabilitation and unsafe mine openings' sealing programs. The pace of the rehabilitation program remains a challenge. The audit therefore recommended finalising the NMCS and adopting its recommendations, alongside a national strategy to reduce state liability (Auditor-General South Africa 2021).

3 Legislation governing mine closure

South Africa's mine closure framework is embedded within a comprehensive interlocking body of legislation spanning mining (MPRDA)(Republic of South Africa 2002), environmental (NEMA)(Republic of South Africa 1998a), water [*National Water Act* (NWA)] (Republic of South Africa 1998b), and health and safety [*Mine Health and Safety Act* (MHSA)] (Republic of South Africa 1996a). The primary goal of these laws is to give effect to Section 24 of the Constitution of the Republic of South Africa (Republic of South Africa 1996b) by ensuring that mineral and petroleum resources are developed in an orderly and environmentally sustainable way, while also encouraging legitimate social and economic growth. Historically, mine closure was not subject to such stringent legislative requirements, with operations focused on surface rehabilitation (such as revegetation, fencing off areas or sealing/filling shafts), while legislation to control water pollution was often not comprehensively implemented. The primary emphasis was placed on economic gains rather than holistic environmental management and rehabilitation under the *Mines and Works Act* (Republic of South Africa 1956) and earlier legislation.

The introduction of the *Minerals Act* (Republic of South Africa 1991) marked a significant shift, requiring submission of an environmental management program, implementation of rehabilitation measures and establishment of financial provision, including the issuing of closure certificates (Swart 2003). Similarly, Alberts et al. (2017) notes that significant reforms have taken place in South Africa's mining and environmental legislation since the introduction of the *Minerals Act*. . At present, the primary statutes governing mine closure and rehabilitation are the MPRDA and the NEMA (Republic of South Africa 2002; Republic of South Africa 1998a).

Mine closure regulation in South Africa has transitioned from its earlier reliance on Section 43 of the MPRDA (Republic of South Africa 2002) to a more integrated framework under the NEMA 107 (Republic of South Africa 1998a) . Specifically, Section 24R of the NEMA, together with the Financial Provisioning Regulations (2015, as amended in 2021) (Republic of South Africa 2015), now governs the requirements for mine closure and rehabilitation.

Under this legislative framework, holders of mining rights or permits are required to manage cumulative environmental impacts and ensure rehabilitation to a sustainable end state. Importantly, environmental liability remains with the operator until a closure certificate is formally issued, even if this obligation extends beyond the anticipated life of the mine.

Moreover, since the adoption of the One Environmental System in 2014, environmental governance for mining has been consolidated under NEMA, with the DMPR serving as the competent authority for implementation. This alignment ensures consistency across sectors, enforcing the 'polluter pays' principle, and strengthens accountability in mine closure practices. Marais (2013), Krause & Snyman (2014) and Alberts et al. (2017) highlight that the One Environmental System was introduced to harmonise the regulatory framework by aligning the MPRDA and NEMA and their supporting environmental management statutes. Water regulation under the NWA is still managed separately, although the regulatory departments cooperate at both local and regional levels. This integration was designed to streamline governance, reduce duplication, and ensure consistency in the regulation of mining and environmental management across South Africa.

The effective implementation of the NEMA is reinforced by a range of complementary environmental management statutes, including the *National Environmental Management: Waste Act* (NEM: WA) (Republic of South Africa 2008), the *National Environmental Management: Biodiversity Act* (NEM: BA) (Republic of South Africa 2004a) and the *National Environmental Management: Air Quality Act* (NEM: AQA) (Republic of South Africa 2004b).

Despite these frameworks, South Africa continues to face challenges with D&O mines that were abandoned prior to the passing of the MPRDA, and especially those prior to the *Minerals Act 1991.* Section 46 of the MPRDA is applicable in this regard, particularly for D&O mines linked to old order rights, empowering the Minister of Mineral and Petroleum Resources to rehabilitate sites where no legally responsible company or individual can be identified. This provision allows the minister to direct rehabilitation measures, authorise the use of financial provision (if any), or allocate state resources to address environmental and public safety risks. This provision underscores the state's role in managing historical liabilities and highlights the importance of robust financial provisioning for current and future mining operations.

However, even though South Africa's legislative and policy frameworks governing mine closure largely align with international best practices (Alberts et al. 2017), some challenges still exist with the rehabilitation of D&O mines. This is compounded by persistent, severe challenges such as the rise of illegal mining (Zama-Zama) on D&O sites. The rehabilitation of some of these D&O mines (for example, asbestos mines) remains a priority because of severe socio-economic and health burdens on communities adjacent to unstable, contaminated and unrehabilitated landscapes (Van Druten & Bekker 2017; Kuipa & Lekunze 2024).

3.1 The case for the draft National Mine Closure Strategy

The draft NMCS (Coetzee et al. 2025) was developed by the DMPR and CGS to address pertinent challenges associated with mine closure in South Africa. Implementation of the NMCS recommendations is expected to change the mine closure landscape in South Africa by changing the narrative of mine closure from a liability to an opportunity (Vadapalli et al. 2025). The draft NMCS is based on 4 pillars (Figure 3).

Figure 3 The 4 pillars of the draft National Mine Closure Strategy

Historically, mine closure has been centred around physical rehabilitation, and the focus has been to bring the land as close to its original state as possible, ignoring the socio-economic impacts of mine closure resulting in migration of the skilled workforce and the decline of the local economy. The draft NMCS took note of this issue and recommended fostering of post-mining economies through concurrent economic diversification and early planning for mine closure, emphasising the legislative and regulatory requirement that physical rehabilitation should be aligned with agreed-to post-mining land use.

Moreover, the declaration of mine closure areas in line with the legislation was recommended. Three categories of mine closure areas have been identified based on (a) interconnection, (b) district municipalities where mining has a substantial footprint and contributes significantly to the economy, and (c) areas where the integrated and cumulative impact of mining extends beyond municipal boundaries and interconnection. Furthermore, where applicable, especially in the case of district municipal closure areas, it is recommended that mine closure plans be aligned with Integrated Development Plans (IDPs) and municipal spatial development frameworks (SDFs), with local development to be informed by the District Development Model (Manungufala 2020). To avoid duplication and have more meaningful impact, mines will then be able to optimise their individual contributions to socio-economic development via their social labour plans, which should align with an agreed-to closure strategy and municipal IDPs. Challenges and key issues related to the issuance of mine closure certificates, premature mine closures with inadequate financial provision,

stakeholder engagement, and other relevant and related matters have been discussed, and recommendations were made in the NMCS.

Therefore, in view of the recommendations of the draft NMCS, it is critical that the framework for the management of D&O mines aligns with the principles of the strategy, since it falls within the realm of mine closure in South Africa.

4 Management of derelict and ownerless mines

4.1 Screening of the database for improved estimation of envisaged financial liability

A process was developed to generate a more accurate estimate of the state's envisaged liability by filtering the database with respect to D&O mines in South Africa (Figure 4). Technically, D&O mines are abandoned mines or mines that relinquished their mining rights prior to the existence of the Minerals Act in 1991 (Republic of South Africa 1956). However, it was observed that the inherited database(s) included records of additional legacy mines operated under different legislative frameworks. As a result, the estimate may not accurately reflect the state's envisaged financial liability and could be overstated, as some of these other legacy mines may have been incorporated into the actuarial study. Therefore, it is important to flag D&O mines in the database that can be used for a revised estimation of the state's envisaged financial liability based on the legislative regime they operated under. This might also result in adjusting the actual number of D&O mines and further classification as stated in Section 2.

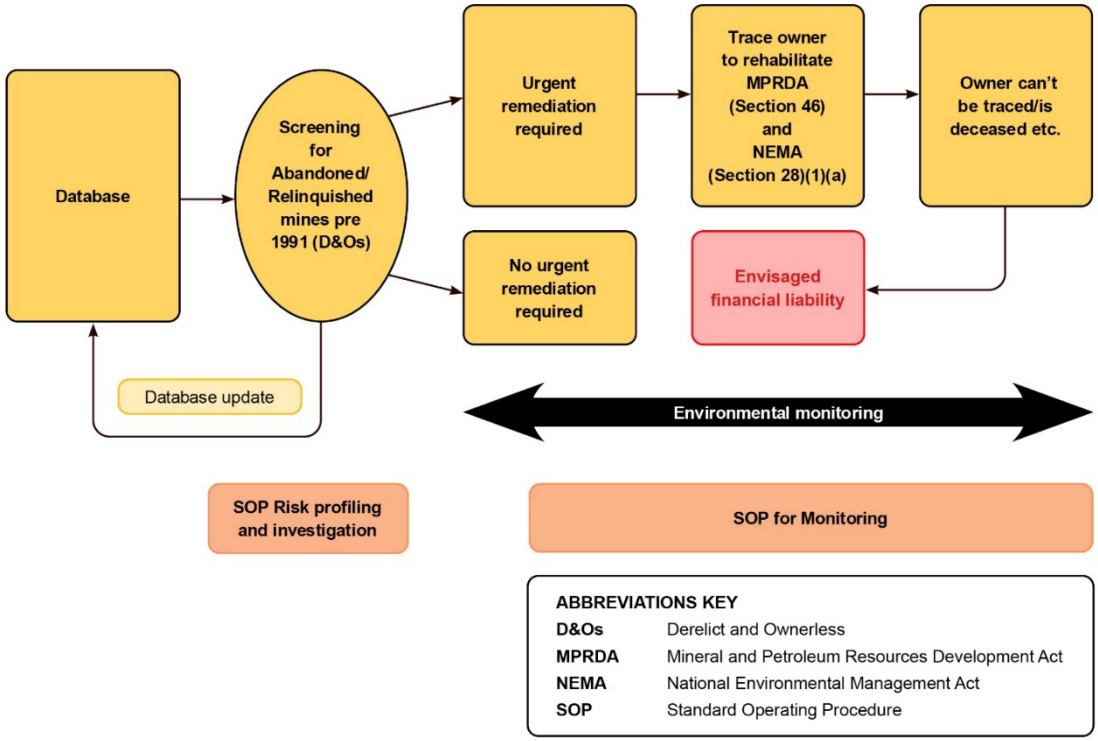

Figure 4 The process to establish improved estimations of envisaged financial liabilities

As previously mentioned, the risk profiling of mines in the database was mainly carried out considering the physical hazards and health and safety risks to the communities. However, it is recommended that a standard operating procedure (SOP) be developed to operationalise the measures recommended to improve risk profiling of these mines, taking physical hazards, health and safety, and environmental risks into account. This SOP will then be used to further filter the D&O mines into 2 categories: (i) mines that require urgent remediation and (ii) mines that do not require urgent remediation. Mines that require urgent remediation will be processed further to trace the responsible owner as per Section 46 of MPRDA (Republic of South Africa

2002) and Section 28(1)(a) of NEMA (Republic of South Africa 1998a), as the legislation can be implemented retrospectively with reference to old order rights and the polluter pays principle, respectively. However, the chances of tracing the responsible owners are often remote, particularly for long-abandoned mines; in such cases, the rehabilitation of some of these D&O mines may become the responsibility of the state. These records will then be used to estimate a revised and improved version of the state's envisaged financial liability. Those mines that do not require urgent remediation will be monitored to detect environmental change, based on an SOP. The revised envisaged liability estimation process is implemented and carefully governed through a project-reporting structure led by the DMPR, with support from the CGS and relevant technical specialists. The D&O database and envisaged liability estimates will be reviewed and updated annually to reflect changes in site conditions, risk profiles and newly available information, thereby improving the accuracy of the state's envisaged liability assessment over time.

4.2 Management of latent impacts in the areas of interconnection

Mines are often clustered, and in some cases are interconnected, as in the case of the Witwatersrand goldfields. These mines have cumulative and integrated impacts on the receiving environment and on socio-economic dynamics in general. Closure planning of these interconnected mines is complicated and can be onerous to 'the last man standing' if not planned early and the apportionment of liabilities is not clearly defined. For instance, in situations involving hydraulically interconnected mines within a mine closure area, the last mine to close may be forced to take the responsibility of pumping water to continue mining operations, especially when there are no prior agreements between the mines and the closure process is not adequately planned. This can lead to undue financial stress and trigger premature closure of more mines (liquidation), and in some instances the liability will be transferred to the state. This is also true for other environmental and apportionment of pollution abatement liabilities. Therefore, a declaration of mine closure areas and establishment of area-based mine closure strategies are pivotal for a sustainable mine closure. Existing mines within a particular mine closure area will amend their individual mine closure plans to align with the area-based closure strategy.

Each of the mine closure area categories briefed in Section 3.1 can include the following scenarios: (i) a mine closure area with all D&O mines, (ii) a mine closure area with a mix of D&O and operational mines and (iii) a mine closure area with all operational mines. The scope of this paper doesn't cover the third scenario (a mine closure area with all operational mines), as this article focuses on D&O mines and their management. In the case of all D&O mines falling within a mine closure area, and subject to the availability of funds, the state may take the necessary measures to prevent pollution or ecological degradation of the environment or address dangerous health and safety occurrences to make the area safe. The state may collaborate with municipalities and align its rehabilitation programs with municipal IDPs and SDFs, and participate in targeted remediation strategies. However, in the mine closure areas with a mix of D&O and operational mines, the state may carry a portion of the shared envisaged liability, and an assessment and apportionment may be considered, subject to the availability of funds. Where consensus cannot be reached between the operational mines and the state, they may agree to engage an independent expert with appropriate experience to determine the liability apportionment for that mine closure area. The challenges and closure requirements may vary between mine closure areas and require a detailed conceptual understanding of site-specific conditions. Again, the state may collaborate with mines and municipalities within that mine closure area and align its rehabilitation programs. In both scenarios (i and ii), where possible, the state may consider collaborating with other role-players to rehabilitate the land in a way that is conducive to the agreed end land use in a mine closure area. In the case of isolated D&O mines that do not fall into any mine closure area, and subject to the availability of funds, the state may be responsible for the rehabilitation work; however, it is not necessary to integrate, and collaborate on, rehabilitation works with other role-players.

4.3 Preliminary process for repurposing derelict and ownerless mines

Repurposing of D&O mines was also acknowledged as one of the interventions to manage D&O mines. A guiding process is required to provide procedural clarity and guidance to decision-makers with the aim of

embarking on or supporting repurposing initiatives. Furthermore, repurposing initiatives are capital-intensive, and the state's fiscus is limited; thus there is a requirement for a process to guide the selection and prioritisation of repurposing sites and strategies, in addition to finding other sources of funding. Ideally such a process ought to assign risk and responsibilities while highlighting potential economic opportunities that could be explored at repurposing sites to reduce the financial burden of rehabilitation and aid in the creation of jobs.

An overview of international and local practices in repurposing abandoned mines broadly identified repurposing end uses as initiatives in renewable energy and infrastructure, environmental sustainability and resource management, as well as economic and recreational developments. The selection of repurposing options should be aligned with the country's strategic objectives and pertinent needs. In South Africa, repurposing options aligned with the Just Energy Transition – the drive towards critical minerals as well as food and water security-related options – may be preferable.

The envisioned preliminary process also assesses the suitability of D&O sites within the database for the aforementioned land use options. Stakeholder engagement and consultation with relevant experts and affected parties should be incorporated as an iterative process and integrated throughout the various phases of the process. The stakeholder engagement process will follow the NEMA stakeholder engagement framework and aim to build consensus among all affected parties wherever possible by designing projects that align with local needs, priorities and skill sets. Furthermore, the repurposing activities will prioritise the utilisation of the locally available workforce by creating employment opportunities and supporting the socio-economic development of surrounding communities. Such an approach will likely aid the socially acceptable repurposing programs and alignment with potential investors. Figure 5 below proposes a broad draft process for shortlisting, and the risk-based prioritisation, of legacy mine sites for various repurposing end uses.

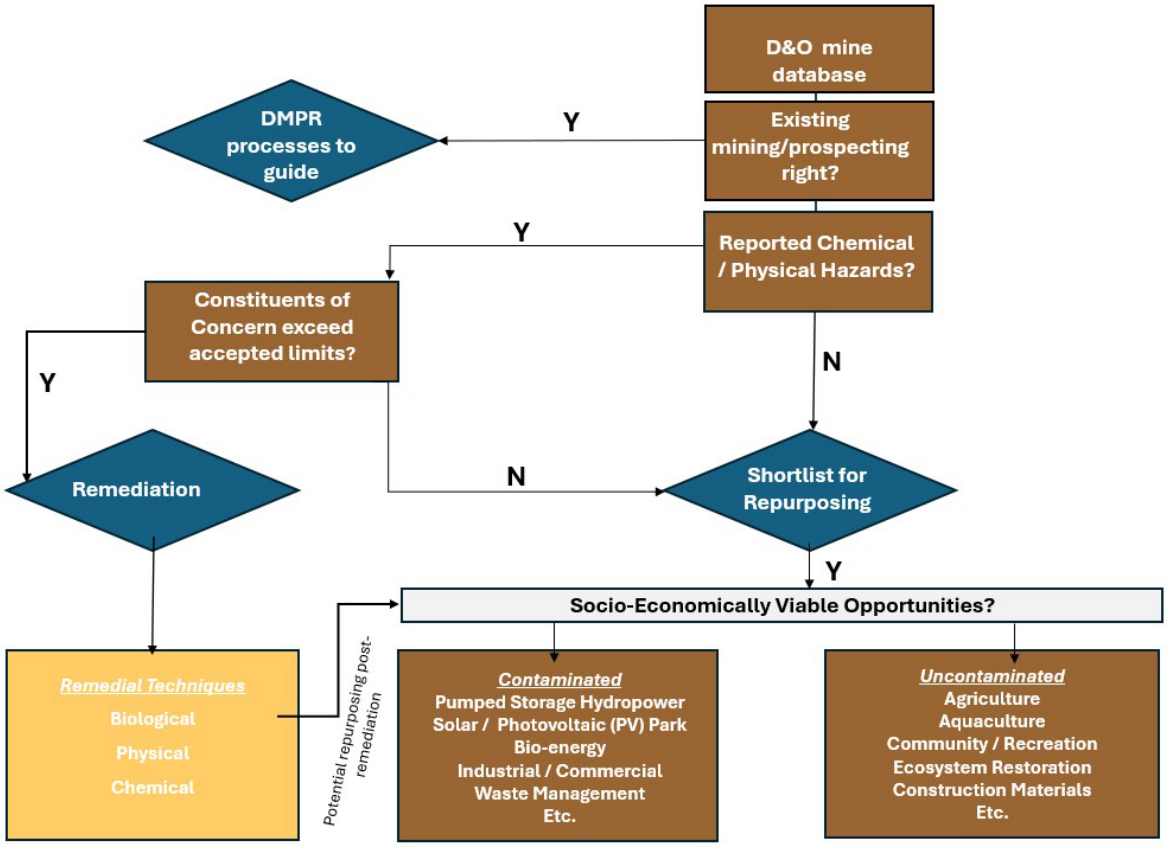

Figure 5 Preliminary process for prioritisation of derelict and ownerless (D&O) sites for repurposing and selection of repurposing end use options. Department of Mineral and Petroleum Resources (DMPR)

The D&O database is currently static. Consequently, record updates are not dynamic, resulting in a lag between the issuance of new mining rights for D&O mines and the updating of records. Therefore, it is critical to establish whether mining rights have been granted on a shortlisted D&O site before a decision is made on repurposing. If rights have been granted, the site must then be excluded from further consideration for repurposing as it is managed through the DMPR's internal processes; these generally require a new mining right holder to assume responsibility for managing future environmental risks and past mining impacts unless a closure certificate is issued for previous mining operations.

To mitigate exposure to contaminants, it is advisable to consider predominantly uncontaminated D&O sites for agricultural, aquacultural and community recreational developments where practicable. Sites determined to be unsafe due to land instability or contamination at concentrations posing environmental and human health risks would require partial or full rehabilitation and thereafter could be considered for repurposing for end uses such as energy and/or industrial options. Ground truthing exercises should then be undertaken to verify site conditions and suitability for the proposed repurposing option. In general, these ground truthing exercises are usually carried out by the CGS after agreement with the DMPR.

Sites eligible for repurposing (i.e. minimally contaminated sites with no existing or pending mining rights) will require further characterisation to aid in the identification of sites requiring immediate intervention. This can include, but is not limited to, classification in terms of the type of mine feature (e.g. shaft, open pit, tailings dam, etc.), the current risk ranking (on the D&O database), its size and geometry, proximity to sensitive receptors, predominant economic activity, commodity type, etc. Where rehabilitation and remediation are required prior to repurposing, SOPs will be required to ensure that the rehabilitation/remediation culminates in the attainment of specified conditions for further development. As far as reasonably practicable, the SOP should highlight the entities responsible for funding, providing technical oversight and monitoring rehabilitation efforts.

Baseline criteria are required to determine the suitability of the listed D&O sites for proposed repurposing alternatives. These may include factors such as terrain, land suitability, water availability, energy potential (e.g. solar irradiance), existing public infrastructure, district spatial planning, and skills and education levels (Cole et al. 2023; Cole et al. 2025; Giri et al. 2025; Singh et al. 2024). In areas where multiple repurposing options are possible, the weighing of the criteria will highlight repurposing options that yield the greatest value to the stakeholders. However, the significance of these factors may vary depending on location, socio-economic conditions, pre-mining conditions at the site, and other local and/or regional conditions.

The draft preliminary process illustrated in Figure 5 focuses on economic opportunities related to infrastructure repurposing and alternative land uses. Re-mining and waste valorisation present additional economic opportunities. The recovery of critical raw minerals from mining waste is a potential pathway towards developing circular economies in and around D&O sites (Nwaila et al. 2021). The Witwatersrand Basin is reported to have produced over 47,000 tonnes of gold between 1886 and 2002, generating approximately 6 billion tonnes of tailings (Mpanza 2024) stored across 270 known mine waste deposit dams covering 400 km^2 in the Gauteng Province alone (Mpanza 2024; Oelofse et al. 2007). The coal industry is the second-largest producer of mine waste, including waste rock, low-quality coal, slurry and fly ash. Approximately 262 Mt of run-of-mine coal was produced in South Africa in 1996, of which around 55 Mt was coal waste (fine and coarse discard, slurry, and unsold duff coal) (Wagner 2008). The discards continue to accumulate at an annual rate of 54 to 60 Mt, and coal discards were estimated at 1.5 Bt in 2011; primarily located in the Witbank coalfield and continuously increasing (Belaid et al. 2013). Various research studies have investigated the potential for valorisation of mine waste (Nwaila et al. 2021; Stander et al. 2025). The properties of such waste are localised and depend on the nature and composition of the mined rock strata, mining techniques and beneficiation processes undertaken. Detailed geometallurgical characterisation of the targeted mine waste stream is required to determine the techno-economic feasibility of repurposing this waste, given current processing techniques, technological constraints and regulatory policies.

5 Conclusion

Existing legislation on mine closure in South Africa is robust, and no major amendments are required to manage derelict and ownerless (D&O) mines. It was noted that a fresh approach to update and screen the D&0 mines database may reduce the envisaged financial liability of the state and enable the prioritisation of rehabilitation of high-risk mines. Risk profiling of D&O mines may consider other environmental pathways to improve relevance. It is recommended that the D&O database be integrated with a proposed mining cadastre for ease in decision-making. The review highlighted that the state may explore collaborative opportunities with other role-players, especially in the areas of interconnection and cumulative integrated impacts to achieve sustainable D&O mine closure. Furthermore, the review also noted that the repurposing opportunities can generate socio-economic benefits but require clearer frameworks, stakeholder involvement and alignment with national priorities, including the Just Energy Transition and circular economy initiatives. However, funding is an issue in managing such a large number of D&O mines, and other avenues, including partnerships with private entities, must be considered in addition to the contribution from the constrained state fiscus. It is important to note that all the recommendations proposed to manage D&O mines in this article are still at a draft stage, preliminary and not final.

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Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used ChatGPT, QuillBot and SciSpace artificial intelligence online versions to improve the sentence construction in a few instances. The authors have reviewed the content and edited it where required and take full responsibility for said content.

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