

Determining the vulnerability of asset retirement obligations across the mining sector

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Abstract

Asset retirement obligations (AROs) detail the corporate liability associated with decommissioning and environmental rehabilitation across a corporate portfolio, i.e. they represent the committed cost of closure across the whole company. An ARO is effectively a debt on a company's balance sheet as the accounting treatment provides a single aggregated number that is discounted for future spend. AROs are opaque, and it is difficult for investors to understand the potential impact of cost increases and non-discretionary annual spending commitments, and consequently the risks that sit within investment portfolios. AROs for major mining organisations have increased substantially, with 11 miners reporting a combined USD 36.2 billion increase between 2015 and 2024, amounting to an 8% year-on-year increase despite individual annual spend of up to USD 1.1 billion (Rio Tinto 2024).

The long-term nature of AROs, with a cost horizon typically exceeding 15 years at the corporate level, places them outside the interest of ratings agencies, which are more concerned with risks within a shorter time frame (<5 years).

ARO vulnerability assesses the potential for cost escalation at the portfolio level. The assessment involves unravelling the ARO to determine the probable total cost of closure at a corporate level and then an assessment of causative factors within the portfolios which would be likely to increase closure costs over the life of the assets within the portfolio. It provides a tool to address corporate closure performance by heightening investor knowledge, enabling modelling of closure impacts on investor portfolios and feeding into a closure/transition mark.

Keywords: ESG performance, closure cost assessment, financial disclosure, closure disclosures, asset retirement obligations, vulnerability, decommissioning, environmental rehabilitation

1 Introduction

Asset retirement obligations (AROs) record the current cost of committed decommissioning (and environmental remediation) actions that a company is obliged to undertake, and along with other publicly reported data provide a window into the level of effort a company is making/needs to make in regard to site closure and clean-up following the winding down of operations.

The AROs for 11 large mining organisations were reported in 2025 to total USD 67.1 billion (Anglo American 2016–2025; Alcoa 2016–2025; BHP 2015–2025; Teck 2017–2025; Glencore 2016–2025; Rio Tinto 2016–2025; South 32 2016–2025; Vale 2016–2025; Barrick 2016–2025; Freeport-McMoRan 2016–2025; Newmont 2016–2025). The same companies reported USD 30.9 billion in their 2015 annual reports. Despite annual spending, this USD 36.2 billion increase represents an aggregate annual compound growth rate of 8.08%. Figure 1 shows this increase for each organisation. It should also be highlighted that all of these organisations spent on ARO-related actions during this period, and that these increases have happened despite the fact that

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expenditure of USD 4.8 billion alone is reported in the 2024 corporate reports (Anglo American 2016–2025; Alcoa 2016–2025; BHP 2016–2025; Teck 2017–2025; Glencore 2016–2025; Rio Tinto 2016–2025; South 32 2016–2025; Vale 2016–2025; Barrick 2016–2025; Freeport-McMoRan 2016–2025; Newmont 2016–2025).

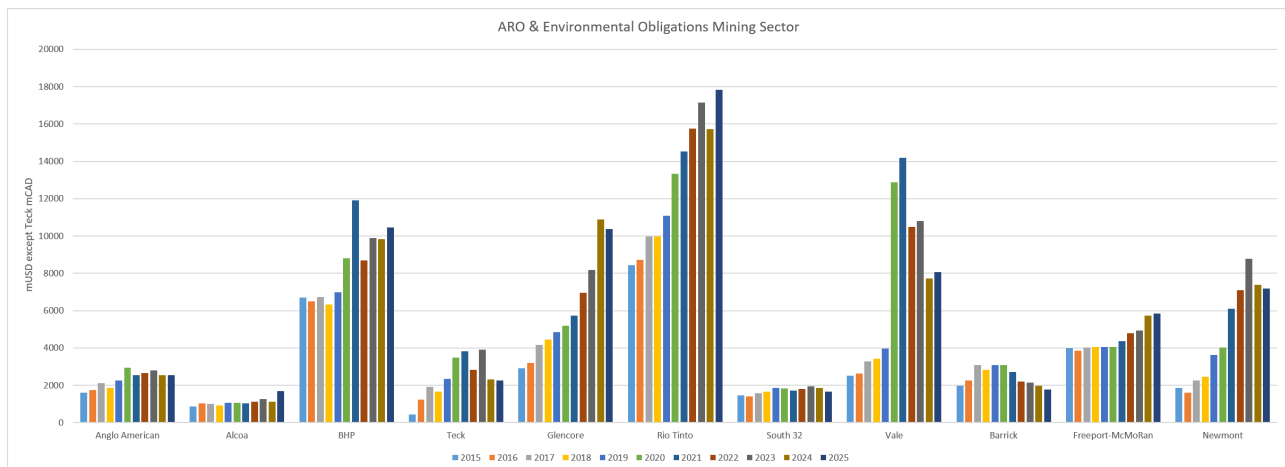


Figure 1 Asset retirement obligations (AROs) for 11 major mining organisations (2015 to 2025 Annual Reports)

The rising ARO levels have sparked investor concern. Moody's (Moody's 2024) published a report outlining the indebtedness and warned that 'the dependence of mining companies on open pit mining that disturbs more of the environment, as well as growing spending on AROs and financial guarantees, could reduce cash flow and liquidity and tie up capital'. Mining 2030 (Mining 2030 2025) listed adequate funding for closure and post-closure transitions as a guiding principle. In June 2025, following publication of a global review (BNP 2025), BNP Paribas Asset Management convened a Global Decommissioning Seminar in London, outlining the challenges faced not just by the mining industry but across several resource sectors. At this event, the Church of England Pensions Board challenged for investor-led solutions. This is not just a mining issue; Investors for Paris Compliance recently organised to vote against the audit committee chairs and auditors at Suncor and Cenovus (Investors for Paris Compliance 2026).

2 Accounting for decommissioning and remediation

Accounting for decommissioning and remediation is outlined in the US Financial Accounting Standards Board (FASB) under Accounting Standards Codification (ASC) 410-20, which requires accounting of the legal obligations associated with the retirement of a tangible long-lived asset, under the normal operation of that asset, including any legal obligations that require disposal of a replaced part that is a component of a tangible long-lived asset (Ernst & Young 2022; Financial Accounting Standards Board 2024). This includes an environmental remediation liability that arises from the normal operation of a long-lived asset and is associated with the retirement of that asset. ASC 410-30 provides for accounting for environmental remediation liability that results from the improper operation of a long-lived asset. Under the International Financial Reporting Standards (IFRS), IAS37 provides for provisions: recognised when there is a present obligation (legal or constructive) from a past event, and it is probable (more likely than not) that an outflow of resources will be required, and the amount can be estimated reliably (IFRS 2026). Under IAS37, these are provisions, contingent liabilities and contingent assets, and include the site decommissioning and remediation costs.

Both the FASB and IFRS Standards provide for the recognition of costs that can be reasonably expected at the time of accounting. This, in turn, means that the ARO provision detailed in accounts (which represent future spend) is discounted to its present value (cost), and ARO is recognised as a debt.

For clarity, when referring to AROs here, this paper includes asset retirement obligations, environmental liabilities and the impact of mining-related disasters.

2.1 Asset retirement obligation transparency: What lies beneath?

ARO figures provide coarse-grained data in relation to the exposure to closure costs. A single figure is provided and aggregated at a company level, with information not generally available at a site or group level; nor are range expectations generally reported (there are some exceptions for elements of the accounting). As noted above, AROs are discounted to show the cost of the obligations in today's money. Organisations have (but not consistently) detailed the average date to closure (which is important for understanding the true cost commitment, i.e. unwinding the discount). Sometimes the average life of mine figure has been weighted by the cost of closure. Different organisations use different discount rates, and multiple discount rates are also used (Glencore has discount rates for USD reporting and for the ZAR rand, while Anglo American applies a variable discount structure against each of 5 separate currencies), with discount rates changing between years.

Discounting obscures the total projected cost of these activities (i.e. the true indebtedness). A number of organisations have called on corporate organisations reporting AROs to be more transparent in their disclosures and to report alongside the ARO figures the undiscounted figures (Carbon Tracker 2025; Climate Action 100+ 2023). Undiscounted costs are being reported by a few organisations; Rio Tinto and Glencore both started reporting them in 2024. Barrick and Freeport-McMoRan have reported undiscounted values for more than a decade. Undiscounted values are sometimes detailed in time tranches.

An interesting aspect/issue (outside the scope of this paper) also exists in the discount rates used and in their alignment with bond yields (Michelon et al. 2020).

Annual spend, transactions and currency fluctuations are also detailed in the corporate reporting notes on AROs. Transactions reflect the ever-changing corporate footprint, and acquisitions or disposals will cause the ARO to be revised. Trades between companies may not be reflected in the same way, with varying ARO impacts as both firms are able to value this independently.

Legacy sites pose a distinct challenge as goals shift from the development and implementation of closure plans to the continued management of long-lived treatment systems. It is difficult to isolate these sites from the overall ARO figures provided, although some organisations do provide limited details. A review of 57 mines (Byrne 2013) that ceased production between 1945 and 2012 showed that only 5 of these have been relinquished with no further company obligations. Of the remaining mines, all are still in care and maintenance, with 58% of these having some form of water treatment. The cost of these operations builds and weighs against productive assets.

Although there are standards that govern AROs, what is reported varies between organisations and is not consistent between auditors. So long as the obligation is reported correctly, the amount of additional disclosure is a matter for individual organisations.

3 Pension funding and mine closure cost estimation

Funding for pensions can be viewed in a similar way to AROs; both are effectively long-term debts, with reserve funds that need to be developed. Pension schemes are now well regulated, and the majority exhibit a low level of systemic risk, with the total funding requirement needing to cover the length of time that a pension will need to be paid to each member. This depends on members' life expectancies and the amount by which pensions will need to increase each year. Where pensions utilise derivatives (stocks, bonds, currency), pension schemes are obliged to use derivatives in a manner that carefully controls risks. Pension funding is understandably cautious, and actuaries generally build these funds with a holistic view of the risks involved. This necessitates a probabilistic approach to understanding outcomes, with funding at a P95 level.

Probabilistic simulation (Monte Carlo analysis), with tools such as Crystal Ball, is a well-established approach for determining the cost of major infrastructure projects and is recommended in a number of guides (Infrastructure and Projects Authority 2021; Risk Engineering Society 2025 etc). Despite this, only 4 papers detailing probabilistic costing approaches have been presented in recent years at the Australian Centre for

Geomechanics Mine Closure Conference (Hesketh et al. 2023; Guerra et al. 2025; Bloemhof & Bothma 2025; Botes et al. 2025).

The cost of closure is progressively developed as mining projects progress through conceptual, pre-feasibility (PFS) and feasibility (FS) stages, until the definitive closure cost is reached (as illustrated in Figure 2). Each of these stages is time-related and impacted by a variety of challenges such as project complexity, limited knowledge base, lack of clarity on the end point, and developing regulatory frameworks. A deterministic costing approach is often utilised with a single-point estimate; components of a project are assigned values based on discrete scenarios that determine a cost outcome, using existing information, limited commercial experience and/or guesstimates. This is then bundled with an often-arbitrary contingency that, in some instances, may not align with the true level of risk.

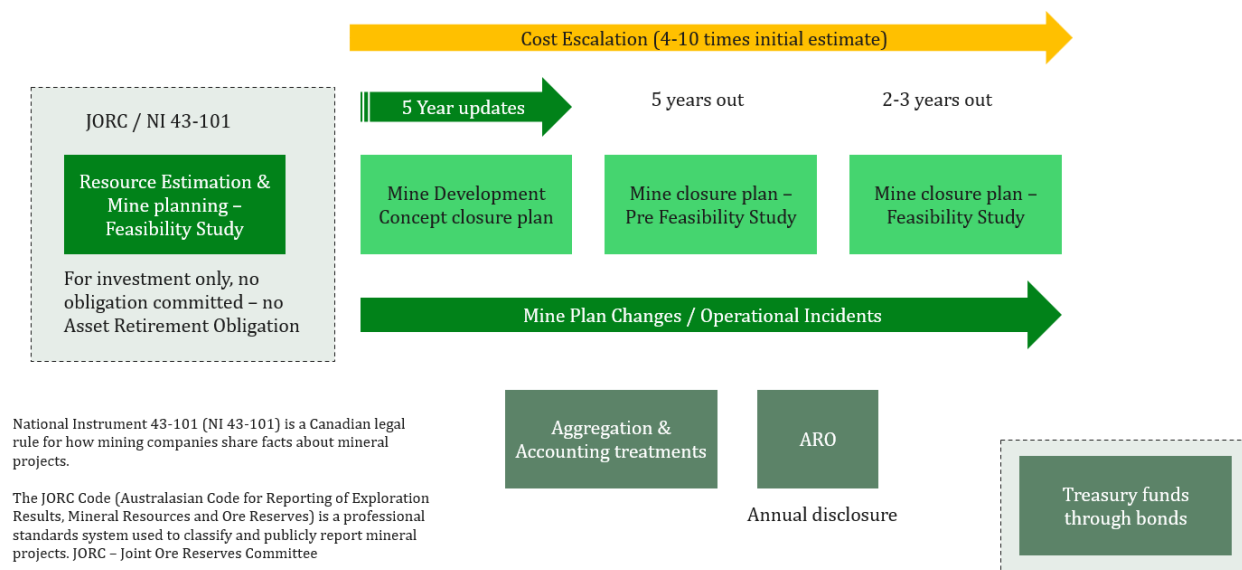


Figure 2 Illustrative typical overview of closure cost development and disclosure

Note also that the draft JORC code (JORC 2024), which provides a global standard for reporting on mineral deposits, has a +/-30–50% accuracy level for closure cost development at the feasibility study stage. This would not introduce an ARO (given that it is pre-mining) but it is illustrative of a mismatch between expectations and costing performance, which is updated and developed as illustrated in Figure 2.

4 Closure cost escalation

Analysis of closure costs has consistently shown large increases, with an upper estimate of 4–10 times recognised (Turner & Townsend 2023; ERM 2023). Closure cost increases are documented for a number of sites, with Energy Resources of Australia's (ERA's) Ranger mine a well-known case. In 2018 it was reported that costs[†] would be '...\$808 million — \$296 million more than ERA's initial \$512-million estimate.' These figures were further revised in 2022 to \$2.2 billion, with ERA saying it '...could cost up to \$1.2 billion more than expected and take two years longer than initially planned.' Then in 2023 it was stated that '...rehabilitation would "materially exceed" \$2.2 billion' (James 2018; Fitzgerald 2022; Energy Resources of Australia 2023). Mine closure consistently represents as a large-scale project and cost increases on individual large-scale projects are well known, with many examples from outside of mining, e.g. the Channel Tunnel and Boston's Big Dig, to name but 2.

[†] Ranger costs reported in AUD

As AROs are discounted, increases in them can be through: (a) a change in the footprint (addition or subtraction of sites), (b) the average closure date becoming closer or moving further away, (c) reduction due to spend (or the removal of elements no longer an obligation), (d) the inclusion of different elements within the program (additional closure cost) or (e) increased knowledge/rates. Undiscounted values provide an opportunity to understand how costs across the portfolio change over time. Illustrative of this, Figure 3 shows the change in reported undiscounted values for environmental obligation in 2015, 2020 and 2024 (Freeport McMoRan 2015, 2020, 2024) reported in one set of corporate accounts. Usefully, the undiscounted values are reported as a range and a central estimate, noting that the relevant reports state ‘it is reasonably possible that these obligations could range between [the upper and lower points]’. This shows a clear escalation in costs that jumps beyond the upper estimate initially reported just a few years earlier (2015–2020), then again so that the central point in 2024 exceeds the 2020 upper limit. With the range itself being tight (-9 to +17%), and if it is reflective of the level of detail available and in line with the American Association of Cost Engineering (AACE) cost estimation (AACE 2022), this would place it as a Class 3 estimate. Clearly this is an external view through a window so the detail behind these costs and why a relatively tight range has been suggested are unknown, but from an investor perspective the range could imply comfort in the level of knowledge; instead of viewing multiple reports, cost escalation as per Figure 4 (from Sanders et al. 2024) appears more appropriate.

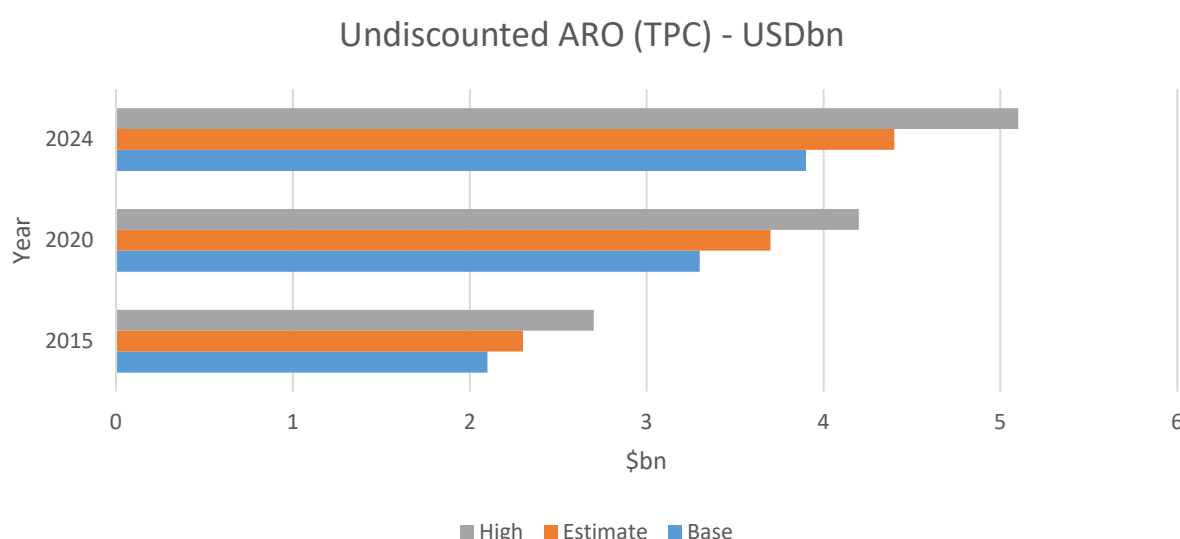


Figure 3 Undiscounted asset retirement obligation (ARO) escalation with materiality limits exceeded

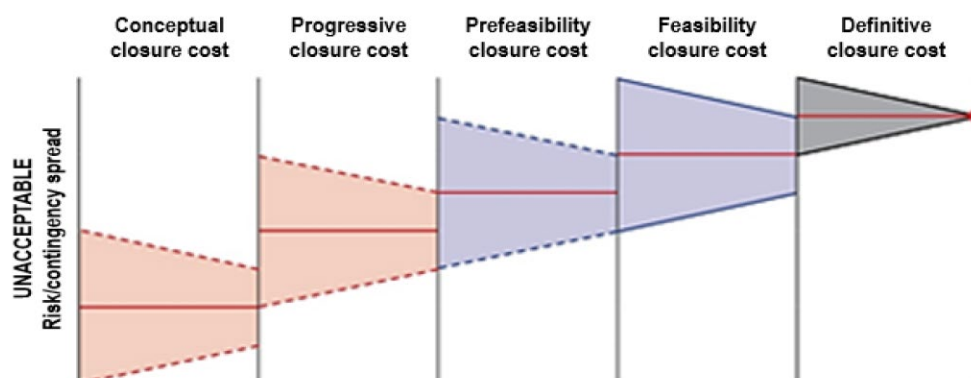


Figure 4 Comparison of likely closure project cost history based on consideration of cost uncertainty (from Sanders et al. 2024, adapted from Department of Transport and Main Roads 2017)

5 Asset retirement obligation vulnerability

An ARO is a statement of what the expected cost of retirement will be for an organisation's assets. ARO numbers are not static; they reflect the obligations in closing and their financial context, such as the unwinding of discount rates (sites getting closer to closure), acquisitions and disposals.

5.1 Asset retirement obligation vulnerability factors

The increasing value of AROs illustrate that the ARO figures contained in corporate accounts are vulnerable to escalation and, from an investor perspective, should be read with a warning. ARO vulnerability is an expression of the understanding that AROs can change beyond the fundamentals and accounting dynamics outlined above, i.e. that an ARO does not truly reflect the future obligation it is meant to define because that obligation itself it is not generally well understood. Factors affecting ARO and promoting additional vulnerability need to be considered across a company's entire portfolio, but include elements such as:

- information currency, closure maturity/time to closure
 - Reports detailing a closure process and related costs can be dated. As sites move progressively towards closure, efforts to determine appropriate actions can become more focused and a better understanding of the need can be obtained. New issues understood, assessed and costed. Climate change models are better defined, and climate mitigation actions are incorporated into designs
- jurisdictions contained within the portfolio and the regulatory maturity of these jurisdictions
 - Jurisdictional vulnerability comes from immaturity. Closure costs within mature organisations could be considered to be evolve and reflect the needs of regulators. In immature jurisdictions, needs will evolve over time and, given long mine lives, this evolution becomes more evident and adds cost
- project execution performance: remoteness and extreme conditions
 - Mining is tough, and sites are often remote and subject to extreme conditions (desert, arctic or high-altitude conditions) which are likely to hinder successful project implementation, and require special planning and, in some case a degree of luck, to avoid adverse conditions
- commodities' potential for environmental impact and the ability to control these risks
 - Different commodities present different risk profiles; for instance, acid conditions may predominate. Commodities with higher risk profiles may have a greater impact on ARO increases
- corporate commitments
 - Corporate commitments can change and can place an additional level of effort on closure programs. Social costs are not included within AROs, but these can be a significant component
- legacy considerations and long-term management needs
 - Legacy operations and the need for long-term management provide an increasing base load to AROs. Operators with more legacy operations or approaches that involve long-term water management have increased cost burdens
- red flag issues
 - Effects such as community impacts that have not yet been realised as AROs need to be considered. Widespread selenium contamination is reported at many coal operations in Canada and in watersheds in the USA, but has not (yet) become a corporate issue

- exposure to shocks
 - Game-changing elements such as the Global Industry Standard on Tailings Management, per- and polyfluoroalkyl substances (PFAS) or talc/amphibole risk exist, and these can add significant cost to an ARO profile as the understanding in relation to these evolves and changes from an intangible issue to a risk and ultimately to an obligation.

Given that the life of mine expectation in many cases is greater than 20 years (and is certainly the current case in across major mining portfolios), it is therefore reasonable to assume that many sites have not yet developed PFS-level closure plans, limited closure cost maturity exists and further ARO increases could be expected. For each of the elements detailed above, a potential dollar impact can be calculated and applied proportionally to a corporate portfolio. This is akin to moving from a P50 most-likely probabilistic determination to a P95-level probabilistic determination.

5.2 Assessing asset retirement obligation vulnerability

Even when undiscounted, ARO does not adequately represent the likely cost of closure and associated environmental clean-up as ARO numbers are vulnerable and prone to further increases. A methodological framework for assessing this vulnerability exists and provides an alternate view on the true cost of exposure that investors are facing.

This framework involves a portfolio-level assessment of the asset base, an unwinding of the ARO and a disaggregation either to a group or a site level. Once the ARO is disaggregated, a factorial approach is applied to understand the risks posed via jurisdictional maturity, geographic factors, commodity impact, existing closure maturity, commitments and red flag elements/shocks. The disaggregated data can then be reaggregated to determine a total project cost for retirement across the company's portfolio and then discounted to provide a comparative value against the original ARO. The percentage change represents an impact factor for investors and can be assessed against the whole sector.

5.3 Closure disclosure

Corporate reporting of the details that sit behind the raw ARO numbers is highly variable. Discount rates, years to closure, expenditure profiles, apportionment and the impact being achieved are not always clearly detailed.

6 Conclusion

Providing reliable asset retirement obligations (AROs) is about building investor confidence; year-on-year increases that cannot be explained through unwinding of a discount or an increased portfolio development can cause mistrust. Worse still, increasing levels of ARO become a proportionally bigger drain on capital that inhibit the ability of organisations to deploy that capital on revenue-generating projects. Legacy and asset management is a rump of activity that needs to be funded from productive resources; long-tail management of sites is not an effective use of resources and, as this grows proportionally, an organisation needs to focus more time/effort to maintain it.

There is a need for additional transparency regarding AROs: what they cover and, importantly, what has been achieved. Closure expenditure needs to be performance-led; closure is the destination (and a point of transition for communities and possible future use) for mine plans. The outputs need to be beneficial, responding to water, nature and communities.

Closure needs appropriate benchmarking across a range of areas. ARO vulnerability is one area that can be calculated. Others could include framing strategic priorities, rehabilitation performance, progress on social and just transition, and community dialogue/participation.

Better disclosures build trust and allow investment decisions to be made with a full awareness of risks. As such they encourage preferential investment, meaning that weaker-performing organisations would be forced to improve practices, thereby improving global outcomes for closure.

ARO vulnerability is an issue that the investment community is waking up to; the increases that have been seen over the last 10 years are systemic and reflect a lack of understanding of what the true cost of closure is, the issues that need to be accommodated and how these issues evolve over the relatively long life of a mine. ARO vulnerability assessment allows a more complete understanding of what the true indebtedness is for a corporation and allows better judgments to be made in investment or corporate transactions.

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