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THE REHABILITATION GAP

Mine Closure Liabilities, Financial Assurance and the Intergenerational Economics of Responsible Extraction

A global, evidence-led assessment of closure funding, technical permanence, post-mining transitions and public financial exposure.

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Research scope: global. No country is ranked. All financial scenarios are illustrative unless expressly attributed to a published source.

Publication integrity statement

This monograph examines the mismatch between the costs required to close mines responsibly and the funds, governance systems, technical evidence and institutional capacity available when production ends. Its central claim is that closure risk is a balance-sheet, public-finance and social-transition issue throughout the mine life cycle, not a final-stage environmental task.

Institutional facts and reported figures are attributed using bracketed reference identifiers [R01] through [R40]. The source register contains institutional names, dates, titles and public source locations. Data from different jurisdictions are not aggregated into a global total because mine types, accounting bases, guarantee rules, currencies and reporting years are not directly comparable.

The original CLOSURE Integrity Framework and associated decision tools are author-developed propositions. The framework does not claim empirical validation, legal status or certification authority. Project-level adoption requires engineering, accounting, legal, environmental and social due diligence.

All cost models in this publication are hypothetical analytical exercises. They demonstrate sensitivities and decision logic, not actual mine costs or forecasts. Source-based statistics preserve their measurement dates. Legislative proposals and tentative accounting changes are not described as enacted requirements.

Publication control: this research is intended for scrutiny by regulators, executives, boards, investors, academics and affected communities. A limitation is disclosed when source coverage is incomplete, legal status differs by jurisdiction, or a proposition rests on judgement rather than direct measurement.

The governing thesis

The credible test of responsible extraction is whether a mine can stop producing without transferring unpriced environmental, financial or social obligations to the public. Closure readiness therefore belongs inside investment approval, mine design, annual budgeting, corporate risk, credit analysis and public oversight.

Evidence classes

Class	Definition	Treatment
Observed	Reported historical or current data	Source, date, population and measurement basis stated
Projected	Modelled future outcomes	Clearly labelled forecast or scenario, not observed
Attributed	Institutional or scholarly interpretation	Named source and relevant limitations retained
Author analysis	Interpretation of verified evidence	Presented as analysis rather than institutional consensus
Author proposition	CLOSURE framework, controls and options	Clearly separated from legal requirements

Executive summary

The hidden balance sheet

Mine closure is often discussed as restoration of disturbed land. A complete liability picture includes decommissioning, earthworks, waste facilities, water treatment, environmental monitoring, social transition, administrative costs, contractor mobilisation, inflation, contingency and, in some settings, obligations that endure for decades. The timing and legal form of these obligations determine whether a provision or security arrangement protects the public.

Why accounting and assurance diverge

Accounting provisions and regulatory financial assurance are related but distinct. IAS 37 and IFRIC 1 address recognition, measurement and changes in decommissioning and restoration liabilities in financial statements. Regulatory assurance seeks accessible funding if an operator defaults. A discounted balance-sheet provision does not establish that a regulator holds liquid, enforceable security. [R11] [R12]

A measurable public-risk problem

British Columbia reported C$4.97 billion of reclamation security against C$5.40 billion of known major-mine liabilities as of 31 March 2024, described by the province as an 8% gap. This is a jurisdiction-specific, dated comparison rather than an estimate of worldwide underfunding. [R03]

Long-tail obligations change the mathematics

Post-closure water treatment can extend beyond a normal mine-finance horizon. Research by Chambers identifies cost modelling, real investment returns and the duration of financial assurance as critical assumptions. A small change in a long-term discount rate can materially alter the capital needed for a fixed annual treatment obligation. [R25]

Financial assurance is a design choice

British Columbia uses site-specific reclamation securities. Queensland combines risk-based fund contributions and sureties. Western Australia operates a pooled rehabilitation fund. Chile and Peru have specific closure-plan and financial-guarantee legislation. These systems are not interchangeable, and none should be judged without its coverage, liquidity, default and release rules. [R02] [R05] [R04] [R07] [R09]

Closure is an operating strategy

Progressive rehabilitation reduces physical exposure while the mine remains profitable. Tailings and water systems require designs that remain stable after active management ends. The Global Industry Standard on Tailings Management explicitly covers closure and post-closure stages. [R14]

Communities face a second closure liability

A technically rehabilitated site can coexist with severe employment, supplier, service and fiscal disruption. Recent scholarship argues for early, inclusive and sustained community participation in social transition planning. Such participation does not guarantee economic diversification, but it makes transition decisions more legitimate and better informed. [R24]

The original analytical contribution

This paper proposes the CLOSURE Integrity Framework: Cost completeness, Liquidity and legal enforceability, Operational rehabilitation, Social transition, Uncertainty and long-tail risk, Regulatory

independence, and Evidence-based release. Each dimension has indicators, failure tests, assurance questions and implementation steps.

The decision principle

A closure system should be tested under operator default, adverse water chemistry, contractor inflation, delayed rehabilitation, premature suspension, extreme rainfall, corporate restructuring and prolonged monitoring. The correct question is not whether the central estimate looks affordable, but whether the public remains protected when the central assumptions fail.

A disciplined implementation pathway

The monograph offers an evidence register, 56-indicator diagnostic, risk-adjusted assurance design, six-stage delivery sequence, board oversight model, scenario tests, country comparisons, public disclosure architecture and a reproducible financial-sensitivity example.

Methodology and analytical boundaries

Source hierarchy

Current laws, regulations, official statistics and audited public reports take priority for factual claims. IFRS material is used for accounting requirements. Academic literature is used to test modelling and participation assumptions. Industry guidance is treated as guidance, not as universal law.

Jurisdiction selection

The comparison covers systems with distinct institutional designs: North American site-specific securities, Australian pooled and risk-rated approaches, South American closure legislation, European extractive-waste guarantees, South African transitional regulation and UK legacy remediation.

Temporal discipline

A 2026 publication can legitimately use 2024 financial balances or 2019 audit findings, but those figures are historical. This paper never relabels a 2017 or 2024 measurement as a 2026 balance.

Comparability

Financial assurance figures cannot be combined across jurisdictions without adjusting for covered activities, currency, price base, discount treatment, permit perimeter, default assumptions and accounting definitions. No synthetic global closure deficit is asserted.

Original analysis

The CLOSURE framework, scorecard, scenario matrices, public-risk waterfall and implementation sequences are author propositions. They are not an endorsed industry standard and have not been field validated.

Exclusions

The study is not a project-specific closure plan, a valuation opinion, an engineering design, legal advice or an assurance certification. It does not rank governments or advocate a particular political actor.

Reproducibility conventions

All illustrative numerical examples use dimensionless cost units or explicitly stated hypothetical currency amounts. Discount rates are assumptions. Where a published source describes a rate

proposal, the text preserves its tentative status. Model equations and sensitivity tables permit independent recalculation.

Part I. The anatomy of closure obligations

The following workstreams define the closure perimeter. Each is treated as a separate cost and evidence object because a single aggregate rehabilitation number can conceal differences in timing, permanence, contractor rates and legal enforceability. The technical observations below are analytical interpretations of the cited guidance and are not site-specific engineering findings.

01. Open-pit landforms and slope stability

TECHNICAL BASIS

Geotechnical performance must be assessed against final pit geometry, groundwater rebound, weathering and public access after mining stops. A design acceptable under active pumping and surveillance may not remain stable when operations cease. [R22] [R15]

COST AND FINANCIAL ASSURANCE

The closure estimate should distinguish regrading, berms, fencing, controlled access, pit-lake management, monitoring instruments and contingency for slope remediation. Contractor pricing should reflect work on an inactive site rather than rates available during full production.

EVIDENCE REQUIRED

Slope deformation, water levels, pore pressures, access controls, inspection records, geotechnical design basis and residual void decisions.

DEFAULT OR FAILURE TEST

A high wall remains accessible after a transfer of ownership and the successor lacks funds to maintain exclusion measures.

The responsible executive should distinguish the physical task, the legal duty, the cash-flow timing and the assurance instrument. A work item may be technically straightforward yet financially difficult if it must be performed after bankruptcy, with incomplete records or without operating infrastructure. Conversely, a costly activity may be reduced through verified progressive rehabilitation, but the reduction should enter the financial model only after performance evidence is accepted.

A credible assurance review therefore begins with an independently verified quantity and scope, adds realistic third-party unit rates and contingencies, tests the planned work sequence against site access and seasonal constraints, and reconciles the result to the instrument held by the regulator. The review should state who updates each assumption and which observable event triggers an increase in security. For obligations extending beyond final works, the estimate should include a funded post-closure monitoring and response mechanism.

Decision layer	Minimum analytical output
Technical	Defined scope, performance criteria and evidence owner
Financial	Cash-flow schedule, third-party cost basis and downside case
Institutional	Permit duty, assurance holder and escalation route
Social / environmental	Affected receptors, consultation and residual-risk register

Author analysis: the materiality of this workstream should be evaluated through the combination of potential consequence, duration, uncertainty, irreversibility and the availability of a credible funded

remedy. A low annual cost sustained for generations can deserve more governance attention than a larger one-off dismantling expense.

02. Tailings storage facilities

TECHNICAL BASIS

Closure of tailings facilities involves long-term geotechnical and hydrological performance, not merely cessation of deposition. Drainage, erosion, seismic exposure and downstream consequence classification influence the monitoring and funding period. [R14] [R35]

COST AND FINANCIAL ASSURANCE

Costing must include final cover or landform design, drainage works, buttressing where required, instrumentation, independent review, emergency preparedness and credible post-closure management. Long-term controls should be engineered rather than assumed to persist without funding.

EVIDENCE REQUIRED

Engineer-of-record files, design-basis report, consequence classification, water balance, independent review, monitoring thresholds and emergency response arrangements.

DEFAULT OR FAILURE TEST

The financial guarantee covers earthworks but excludes years of geotechnical monitoring and treatment after the operator dissolves.

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03. Acid rock drainage and geochemical stability

TECHNICAL BASIS

Potentially acid-generating material creates chemical obligations that may persist beyond the production horizon. The important distinction is between a stable physical landform and a geochemically stable system. [R22] [R25]

COST AND FINANCIAL ASSURANCE

Estimate segregation, encapsulation, covers, collection, treatment, reagent supply, sludge management, energy, staffing and long-term monitoring. Do not assume treatment ends when the mine licence expires.

EVIDENCE REQUIRED

Static and kinetic testing, humidity-cell data, field trials, water quality trends, geochemical mass balance and contingency treatment capacity.

DEFAULT OR FAILURE TEST

An optimistic closure estimate assumes passive attenuation despite field evidence of persistent contaminant loading.

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04. Perpetual or very long-term mine-water treatment

TECHNICAL BASIS

Water-treatment obligations create a duration mismatch between a finite mine and a potentially indefinite environmental service. Small errors in assumed annual cost or real return compound over long periods. [R25] [R19] [R20]

COST AND FINANCIAL ASSURANCE

Model operating expenditure, capital replacement, energy, reagents, sludge disposal, treatment performance, regulatory changes and fund investment returns separately. Compare finite horizons with a conservative perpetuity proxy.

EVIDENCE REQUIRED

Flow and chemistry time series, seasonal variability, plant reliability, electricity tariff assumptions, reagent procurement, treatment residues and reserve replacement plans.

DEFAULT OR FAILURE TEST

A trust is capitalised on an aggressive return assumption and cannot finance treatment after several years of weak markets.

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05. Heap-leach facilities and residual process solutions

TECHNICAL BASIS

Leach pads, ponds and process circuits retain chemical and hydraulic risk after production ends. Rinsing, detoxification and water balance control are operational processes, not one-off earthworks. [R22] [R15]

COST AND FINANCIAL ASSURANCE

Include solution inventory, rinsing duration, reagent use, residual metal recovery where relevant, liner integrity, seepage collection, pond closure and long-term groundwater monitoring.

EVIDENCE REQUIRED

Process inventory, chemical residuals, pad permeability, seepage monitoring, water balance, liner testing and contingency pond capacity.

DEFAULT OR FAILURE TEST

A sudden suspension leaves active solution ponds and no funded operating team for safe management.

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06. Underground openings and ground control

TECHNICAL BASIS

Underground closure must manage shafts, declines, portals, ventilation raises, subsidence and water rebound. Surface hazard inventories need a different approach from underground structural assessment. [R16] [R17]

COST AND FINANCIAL ASSURANCE

Budget engineered seals, backfill, shaft caps, access restriction, geotechnical checks, pump removal and post-closure inspections. Consider whether future access for water treatment or monitoring must remain available.

EVIDENCE REQUIRED

As-built plans, survey data, ground support condition, water rebound model, surface subsidence monitoring and sealed-opening register.

DEFAULT OR FAILURE TEST

A sealed portal fails after land ownership changes because inspection and maintenance responsibility was not legally transferred.

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07. Subsidence and legacy ground movement

TECHNICAL BASIS

Subsidence risk may emerge long after extraction, particularly where historical workings are incompletely mapped. A closure plan must distinguish known engineered hazards from uncertain legacy features. [R19] [R16]

COST AND FINANCIAL ASSURANCE

Cost investigation, geophysics, monitoring, remediation, emergency response and public communication. Do not treat an incomplete inventory as proof of absence.

EVIDENCE REQUIRED

Mine plans, borehole records, historical archives, remote sensing, ground movement measurements and hazard response procedures.

DEFAULT OR FAILURE TEST

Housing development proceeds on a former mining area before subsidence information is made available to planners.

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08. Topsoil, land capability and erosion

TECHNICAL BASIS

Restoration success depends on soil function, slope geometry, seed bank, compaction, hydrology and climatic conditions. Surface greenness alone does not establish ecological recovery. [R22] [R21]

COST AND FINANCIAL ASSURANCE

Estimate soil salvage, storage losses, ripping, amendments, erosion control, revegetation, replanting and multi-season monitoring. Include maintenance and remedial works after initial completion.

EVIDENCE REQUIRED

Soil depth, organic matter, infiltration, vegetation cover, species composition, erosion rates and reference-site performance.

DEFAULT OR FAILURE TEST

A bond is released after one favourable growing season and revegetation fails during a subsequent drought.

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09. Biodiversity and ecosystem recovery

TECHNICAL BASIS

A mine may create habitat fragmentation and ecological effects that cannot be captured by disturbed hectares alone. Restoration targets require an agreed ecological reference and time horizon. [R15] [R22]

COST AND FINANCIAL ASSURANCE

Separate legal offsets from on-site rehabilitation. Model invasive species, habitat connectivity, monitoring, maintenance and residual impacts with realistic ecological timescales.

EVIDENCE REQUIRED

Species baselines, habitat condition, connectivity maps, ecological success criteria and independent monitoring.

DEFAULT OR FAILURE TEST

A nominal restoration target is met by vegetation cover while the original habitat function remains absent.

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10. Groundwater rebound and hydrogeological change

TECHNICAL BASIS

When dewatering stops, groundwater levels and gradients may change, affecting water quality, pit lakes, surface flows and nearby users. The closure hydrogeological model must represent the post-mining state. [R25] [R22]

COST AND FINANCIAL ASSURANCE

Include predictive modelling, monitoring bores, treatment contingencies, well protection and potential pumping or hydraulic controls. The cost estimate should be revised when observed rebound differs from the model.

EVIDENCE REQUIRED

Groundwater heads, hydraulic conductivity, water chemistry, user abstraction, seasonal recharge and model calibration records.

DEFAULT OR FAILURE TEST

A mine transfers the site before rebound reaches equilibrium, leaving an unpriced treatment obligation.

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11. Surface water and extreme rainfall

TECHNICAL BASIS

Closure structures must perform without production-stage maintenance under storms, floods and changing runoff conditions. Design standards need to be assessed against consequence and expected life. [R14] [R22]

COST AND FINANCIAL ASSURANCE

Budget spillways, diversion channels, erosion protection, sediment control, emergency access and maintenance. Include stress tests for rainfall outside historical operating experience.

EVIDENCE REQUIRED

Hydrological design events, catchment changes, rainfall records, flood maps, drainage inspections and climate sensitivity assumptions.

DEFAULT OR FAILURE TEST

A drainage structure is designed for a short closure period but must remain functional for decades.

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12. Process plant and hazardous-material decommissioning

TECHNICAL BASIS

Plants contain electrical systems, chemicals, fuels, asbestos or other materials requiring controlled removal. Demolition values and salvage credits depend on market and access conditions. [R22] [R28]

COST AND FINANCIAL ASSURANCE

Use contractor-based demolition estimates, hazardous-material surveys, transport and disposal pricing, utility isolation, contamination sampling and contingency. Apply conservative salvage assumptions.

EVIDENCE REQUIRED

Asset inventory, material safety records, contamination surveys, dismantling method statements and disposal permits.

DEFAULT OR FAILURE TEST

A closure budget relies on optimistic scrap revenue that disappears when commodity prices fall.

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13. Roads, camps, airstrips and linear infrastructure

TECHNICAL BASIS

Infrastructure can be retained, transferred or removed. Each option has different safety, maintenance, land-rights and funding consequences. [R15] [R24]

COST AND FINANCIAL ASSURANCE

Cost decommissioning and handover separately. A transfer should include an identified receiving entity, asset condition survey, operating budget and legal acceptance.

EVIDENCE REQUIRED

Asset registers, land titles, permits, maintenance history, beneficiary consultations and lifecycle cost estimates.

DEFAULT OR FAILURE TEST

A road is handed to a local authority without the funding or technical capacity to maintain it.

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14. Power systems and renewable repurposing

TECHNICAL BASIS

Grid connections, substations, generators, solar arrays and storage may have productive post-mining uses, but reuse does not eliminate safety and closure obligations. [R21] [R34]

COST AND FINANCIAL ASSURANCE

Compare dismantling, sale and transfer using net present cost, reliability, land rights, recycling and maintenance needs. Any reuse benefit should be contractually credible before reducing assurance.

EVIDENCE REQUIRED

Electrical condition reports, interconnection rights, battery end-of-life plans, load forecasts and receiving-entity capacity.

DEFAULT OR FAILURE TEST

A speculative renewable reuse plan is credited against the bond although no operator has accepted the assets.

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15. Land tenure, cultural heritage and Indigenous rights

TECHNICAL BASIS

Closure alters access, land use, cultural sites and the distribution of future environmental responsibilities. Rights holders and affected communities may define success differently from technical regulators. [R24] [R15]

COST AND FINANCIAL ASSURANCE

Budget consultation, land surveys, remediation of access restrictions, heritage protection, grievance resolution and long-term stewardship arrangements. Legal obligations vary by jurisdiction.

EVIDENCE REQUIRED

Tenure maps, agreements, heritage inventories, participation records, consent processes where applicable and land-use plans.

DEFAULT OR FAILURE TEST

A closure certificate is sought without resolving community access or land-use obligations recorded in agreements.

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16. Workforce transition and retraining

TECHNICAL BASIS

Employment losses can arrive before final physical closure. Workforce transition therefore requires early forecasts, social dialogue and training linked to actual labour-market opportunities. [R23] [R24]

COST AND FINANCIAL ASSURANCE

Model severance, retraining, relocation support, placement services and contractor demobilisation. Distinguish legally enforceable obligations from voluntary transition investment.

EVIDENCE REQUIRED

Skills inventory, workforce demographics, local job vacancies, training completion, placement rates and household impact studies.

DEFAULT OR FAILURE TEST

A company announces retraining near closure without viable employers or sufficient time for qualification.

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17. Local supplier and SME transition

TECHNICAL BASIS

Mine-dependent suppliers often invest in equipment and working capital around one large customer. Abrupt closure can cause defaults, job losses and stranded local assets. [R24] [R15]

COST AND FINANCIAL ASSURANCE

Map concentration exposure and transition services. Consider early contract signals, payment discipline, supplier diversification, technical certification and finance access.

EVIDENCE REQUIRED

Supplier spend by category, customer concentration, contract duration, arrears, local employment and alternative market demand.

DEFAULT OR FAILURE TEST

A supplier-development programme reports procurement growth but never measures dependence on the mine.

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18. Municipal revenue and public-service continuity

TECHNICAL BASIS

Mining towns may depend on taxes, service contracts, infrastructure support and household spending linked to the operation. Physical rehabilitation alone does not protect fiscal continuity. [R24] [R23]

COST AND FINANCIAL ASSURANCE

Build a local fiscal exposure map and distinguish mandatory company commitments from public responsibilities. Plan for service transition and realistic revenue diversification.

EVIDENCE REQUIRED

Local budget, mine-linked revenue, public payroll, utility subsidies, service assets and demographic projections.

DEFAULT OR FAILURE TEST

A municipality inherits water or road infrastructure with a maintenance burden larger than its post-mining revenue.

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19. Public health, exposure and long-term surveillance

TECHNICAL BASIS

Residual contamination, dust, unstable structures and water-quality concerns may require public-health monitoring after production. Surveillance should follow exposure pathways, not vague reassurance. [R22] [R14]

COST AND FINANCIAL ASSURANCE

Specify testing, reporting, referral pathways, independent laboratories and funding duration. Health surveillance must respect privacy and avoid implying causal attribution without evidence.

EVIDENCE REQUIRED

Exposure maps, water and soil testing, health-system capacity, incident records and risk communication protocols.

DEFAULT OR FAILURE TEST

A long-term monitoring commitment has no funded institution responsible for sampling and reporting.

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20. Care and maintenance versus final closure

TECHNICAL BASIS

Temporary suspension may become indefinite when prices, permits or ownership change. Care and maintenance can leave active environmental systems requiring immediate cash even before formal closure is declared. [R01] [R28]

COST AND FINANCIAL ASSURANCE

Model staffing, pumping, security, inspections, water treatment, critical maintenance and restart or closure triggers. Set maximum review intervals and financial assurance step-ups.

EVIDENCE REQUIRED

Operating status, cash runway, minimum environmental staffing, water balance, asset condition and corporate solvency indicators.

DEFAULT OR FAILURE TEST

A distressed operator enters care and maintenance with no funds to keep treatment systems operating.

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21. Contractor mobilisation and third-party default costs

TECHNICAL BASIS

A regulator or trustee closing a failed mine will not enjoy the operator's integrated labour, equipment, procurement or tax position. Emergency mobilisation raises costs. [R01] [R29]

COST AND FINANCIAL ASSURANCE

Use independent third-party unit rates, project management, access, safety, temporary facilities, insurance, tender risk and demobilisation. Apply contingency for incomplete records.

EVIDENCE REQUIRED

Independent quantity survey, contractor quotations, site access plan, cost indices and procurement schedule.

DEFAULT OR FAILURE TEST

A bond estimate uses in-house marginal rates although closure after default requires external contractors.

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22. Corporate restructuring, sale and ownership transfer

TECHNICAL BASIS

A mine can change owners many times while closure obligations persist. The financial strength of the current operator and the enforceability of historic obligations are separate questions. [R02] [R28]

COST AND FINANCIAL ASSURANCE

Review change-of-control clauses, security substitution, parent guarantees, ring-fenced trusts and regulatory consent. Transfers should not release security before replacement instruments become effective.

EVIDENCE REQUIRED

Corporate structure, beneficial ownership, credit support, guarantee terms, sale agreements and licence transfer approvals.

DEFAULT OR FAILURE TEST

An operating subsidiary is sold to a weakly capitalised entity and the original parent guarantee expires.

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23. Accounting provisions and regulatory assurance

TECHNICAL BASIS

Financial reporting measures obligations under accounting rules. Financial assurance secures funds against operator default. The two numbers can differ for legitimate reasons and should be reconciled, not mechanically equated. [R11] [R12] [R13]

COST AND FINANCIAL ASSURANCE

Build a reconciliation of scope, cost basis, discount rate, timing, tax treatment, contingencies and legal security. Boards should review both values and the reasons for the difference.

EVIDENCE REQUIRED

Audited financial statements, closure model, regulator bond schedule, discount assumptions, cash-flow timing and legal instruments.

DEFAULT OR FAILURE TEST

A board treats a discounted provision as proof that cash or a callable guarantee exists.

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24. Insurance, surety and bank guarantees

TECHNICAL BASIS

Different instruments have different liquidity, renewal, collateral and counterparty characteristics. The face value alone does not establish availability in default. [R02] [R05] [R28]

COST AND FINANCIAL ASSURANCE

Review claims triggers, exclusions, expiry, jurisdiction, issuer credit, replacement risk, collateral and drawdown process. Concentration across issuers should be measured.

EVIDENCE REQUIRED

Policy or bond wording, bank ratings, legal opinions, renewal calendar, collateral arrangements and claims testing.

DEFAULT OR FAILURE TEST

A surety expires during insolvency proceedings or is disputed because the regulator cannot meet a claims condition.

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25. Trust funds and long-tail investment risk

TECHNICAL BASIS

A dedicated fund for post-closure treatment converts a recurring service obligation into an investment and governance problem. Real returns, fees, inflation and drawdown rules determine sufficiency. [R25] [R20]

COST AND FINANCIAL ASSURANCE

Model conservative real returns, investment losses, replacement capital expenditure, fees and governance costs. Define investment mandate, trustee independence and recourse when performance falls below assumptions.

EVIDENCE REQUIRED

Investment policy, actuarial assumptions, stress tests, drawdown rules, reserve targets and audit reports.

DEFAULT OR FAILURE TEST

The fund relies on equity-market returns that are incompatible with its essential treatment obligations.

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26. Pooled rehabilitation funds

TECHNICAL BASIS

A pooled levy spreads certain abandoned-site risks but creates cross-subsidy, selection and accumulation questions. The scheme may coexist with site-specific security. [R04] [R05] [R32]

COST AND FINANCIAL ASSURANCE

Evaluate eligible claims, contribution formula, reserve adequacy, investment policy, moral hazard and risk differentiation. Do not assume pooled assets cover every site-specific obligation.

EVIDENCE REQUIRED

Fund statements, contribution rates, site inventory, claims history, investment policy and statutory coverage.

DEFAULT OR FAILURE TEST

A pooled fund is portrayed as full insurance although high-risk operators contribute less than expected default costs.

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27. Regulatory independence and information systems

TECHNICAL BASIS

A technically correct cost estimate is weak protection if regulators cannot verify site data, update the estimate or enforce instruments. Institutional capacity is part of assurance quality. [R29] [R40]

COST AND FINANCIAL ASSURANCE

Separate technical review, licence approval, bond custody and release authority. Establish interoperable mine-site records and independent audit trails.

EVIDENCE REQUIRED

Permit database, inspection history, spatial disturbance data, security register, assurance review dates and staff capacity.

DEFAULT OR FAILURE TEST

A regulator aggregates bonds across mines, allowing surpluses at one operation to conceal shortfalls at another.

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28. Residual risks and relinquishment

TECHNICAL BASIS

Relinquishment transfers legal responsibility after agreed closure conditions are satisfied. Some sites retain residual risks requiring monitoring or institutional controls, complicating final release. [R26] [R14]

COST AND FINANCIAL ASSURANCE

Define success criteria, post-closure period, residual-risk financing, receiving institution and reopening triggers. Distinguish completion of works from evidence of durable performance.

EVIDENCE REQUIRED

Independent completion audit, long-term monitoring, land-use controls, residual risk assessment and signed transfer instruments.

DEFAULT OR FAILURE TEST

A closure certificate ends corporate responsibility before water quality and landform stability have been demonstrated.

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29. Climate adaptation in closure design

TECHNICAL BASIS

Changing rainfall, drought, wildfire, heat and extreme events can affect rehabilitation performance and water systems over a long post-closure period. [R14] [R22]

COST AND FINANCIAL ASSURANCE

Stress-test design criteria, water storage, drainage, vegetation and emergency access. Do not use one climate scenario as a precise forecast.

EVIDENCE REQUIRED

Climate hazard screening, rainfall records, hydraulic capacity, erosion monitoring and adaptive management thresholds.

DEFAULT OR FAILURE TEST

A closure design assumes historical rainfall statistics remain stationary over an exceptionally long asset life.

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30. Historic and orphaned mine inventories

TECHNICAL BASIS

Legacy sites may lack identifiable responsible parties, complete plans or known liabilities. Governments need risk-based inventories before they can prioritise remediation. [R16] [R17]

COST AND FINANCIAL ASSURANCE

Classify hazards by consequence, exposure, environmental pathway, uncertainty and feasible intervention. Avoid treating a count of features as a count of mines or a cost estimate.

EVIDENCE REQUIRED

Geospatial inventory, site inspection, water quality, land use, ownership history and mitigation status.

DEFAULT OR FAILURE TEST

A headline inventory number is interpreted as a precise count of mines requiring equal cleanup expenditure.

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31. Closure governance in artisanal and small-scale mining

TECHNICAL BASIS

Small operators may lack formal records, engineering resources and access to financial instruments. Uniform large-mine requirements can be impractical without tailored administration. [R15] [R16]

COST AND FINANCIAL ASSURANCE

Combine proportionate permitting, shared technical services, progressive rehabilitation, accessible guarantees and formalisation incentives. Enforcement must distinguish inability from deliberate evasion.

EVIDENCE REQUIRED

Operator registry, disturbed areas, water impacts, site clusters, community exposure and accessible rehabilitation methods.

DEFAULT OR FAILURE TEST

Regulatory thresholds push operators into informality, leaving more land without any funded closure obligation.

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Social / environmental	Affected receptors, consultation and residual-risk register

Author analysis: the materiality of this workstream should be evaluated through the combination of potential consequence, duration, uncertainty, irreversibility and the availability of a credible funded remedy. A low annual cost sustained for generations can deserve more governance attention than a larger one-off dismantling expense.

32. Post-mining land reuse and redevelopment

TECHNICAL BASIS

Industrial parks, recreation, conservation, renewable energy and housing are possible reuse pathways, but a reuse concept does not remove remediation obligations. [R21] [R24]

COST AND FINANCIAL ASSURANCE

Use independent feasibility, zoning, liability allocation, environmental suitability, infrastructure costs and demand testing. Record who pays if the reuse fails.

EVIDENCE REQUIRED

Land-use plans, contamination clearance, infrastructure condition, market demand, legal transfer and community participation.

DEFAULT OR FAILURE TEST

Speculative redevelopment proceeds are deducted from the bond before any buyer, permit or financing exists.

The responsible executive should distinguish the physical task, the legal duty, the cash-flow timing and the assurance instrument. A work item may be technically straightforward yet financially

difficult if it must be performed after bankruptcy, with incomplete records or without operating infrastructure. Conversely, a costly activity may be reduced through verified progressive rehabilitation, but the reduction should enter the financial model only after performance evidence is accepted.

A credible assurance review therefore begins with an independently verified quantity and scope, adds realistic third-party unit rates and contingencies, tests the planned work sequence against site access and seasonal constraints, and reconciles the result to the instrument held by the regulator. The review should state who updates each assumption and which observable event triggers an increase in security. For obligations extending beyond final works, the estimate should include a funded post-closure monitoring and response mechanism.

Decision layer	Minimum analytical output
Technical	Defined scope, performance criteria and evidence owner
Financial	Cash-flow schedule, third-party cost basis and downside case
Institutional	Permit duty, assurance holder and escalation route
Social / environmental	Affected receptors, consultation and residual-risk register

Author analysis: the materiality of this workstream should be evaluated through the combination of potential consequence, duration, uncertainty, irreversibility and the availability of a credible funded remedy. A low annual cost sustained for generations can deserve more governance attention than a larger one-off dismantling expense.

Part II. Financial architecture and the economics of long-tail obligations

Accounting provisions and regulatory security are different objects

IAS 37 establishes principles for recognising and measuring provisions, while IFRIC 1 addresses subsequent changes in existing decommissioning, restoration and similar liabilities. The accounting framework is designed to report a present obligation and changes in the asset and liability. Regulatory financial assurance is designed to secure funds or credit support for performance if the operator fails. The two serve different users and have different failure conditions. [R11] [R12]

For an illustrative mine, an accounting provision might use a discounted sequence of future closure cash flows while a regulator demands an instrument based on independently executed third-party work and a different contingency basis. Neither number is automatically erroneous. The error arises when management assumes the provision is liquid collateral, or when a regulator assumes an instrument is sufficient merely because its face value resembles a financial statement line.

IASB proposals concerning provisions and discount rates were still under redeliberation in the September 2025 update. The Board tentatively supported a risk-free discount-rate approach without a non-performance-risk adjustment, but a tentative decision is not an enacted accounting amendment. This distinction matters for comparative analysis of published corporate accounts. [R13] [R38]

A useful reconciliation has at least eight rows: scope, quantity, cost base, contractor rate, timing, inflation, discount rate, contingency and instrument accessibility. The board should ask the finance team to explain each difference and the regulator to confirm which risks its assurance covers. The reconciliation should not force the values to be equal. It should make differences visible and defensible.

Dimension	Accounting provision	Regulatory assurance

Primary purpose	Report a present obligation in financial statements	Secure performance or funding after default
Measurement	Accounting standard and management estimates	Statute, licence, regulator method and contractor costs
Timing	Discounted cash flows may apply	Security can be callable now
Counterparty	Entity and auditor	Regulator, issuer, trustee and operator
Failure mode	Understatement or volatility in reported liability	Unavailable or insufficient funds when work is required
Release	Accounting derecognition criteria	Regulatory evidence and formal release conditions

A transparent illustrative present-value model

Let C_t denote a real closure cash flow at time t and r a real discount rate. The illustrative present value is PV = sum from t = 1 to N of C_t / (1+r)^t. For a level annual real treatment cost C, the annuity approximation is PV = C[1-(1+r)^(-N)]/r. For a perpetual level payment with a positive constant real rate, the mathematical limit is C/r. These formulas are analytical tools, not a statement of any jurisdiction's legal bond calculation.

The assumptions are restrictive. Real treatment cost may change with chemistry, flow, power tariffs, labour, plant replacement, regulatory standards or climate. Real investment returns can be negative for extended periods. A fund needs liquidity, governance, investment restrictions and reserves for capital replacement. The algebra therefore sets a starting point, not a sufficient funding policy. [R25]

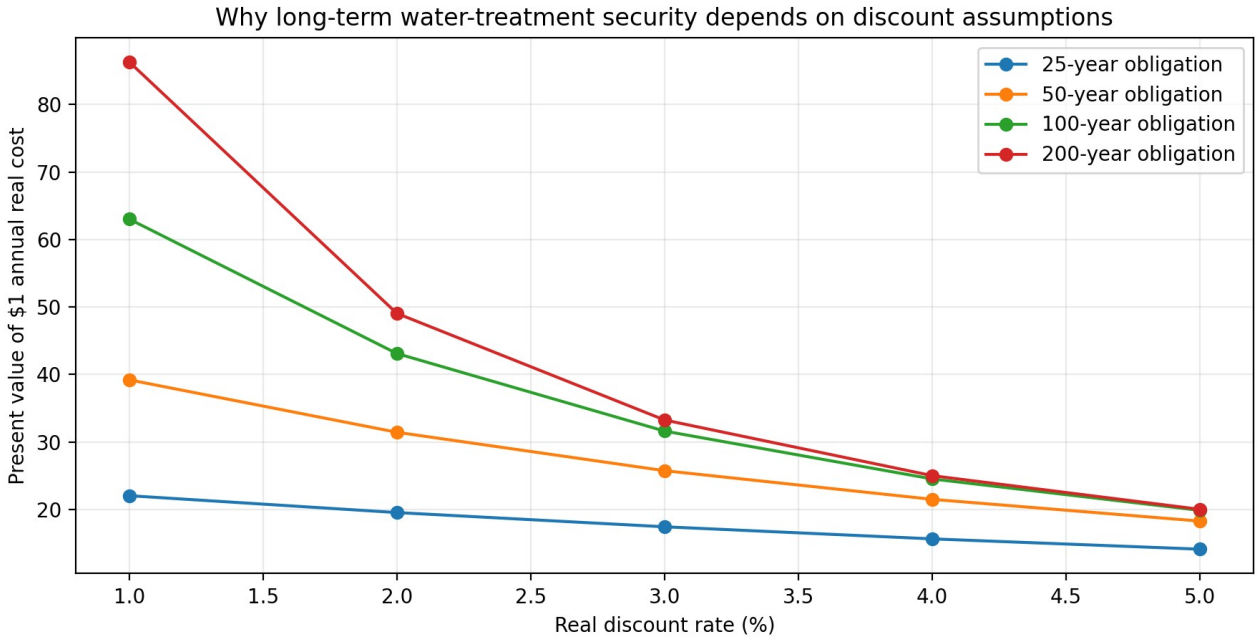


Figure 1. Present value of a hypothetical constant annual real payment of 1 cost unit. Model illustration, not a mine-level estimate.

Horizon	1% real	2% real	3% real	4% real
25 years	22.0	19.5	17.4	15.6
50 years	39.2	31.4	25.7	21.5
100 years	63.0	43.1	31.6	24.5
Perpetuity	100.0	50.0	33.3	25.0

Interpretation: a perpetual annual real obligation of one unit implies 100 units of capital at a 1% real return and 25 units at a 4% real return, before taxes, fees, volatility, capital replacement or contingency. A fourfold difference generated by a model assumption is a governance issue, not a

rounding error. A regulator should therefore require sensitivity analysis rather than accepting a single unexplained rate.

Inflation, escalation and discount-rate mismatch

Closure costs can escalate through labour, energy, materials, contractor mobilisation, environmental standards and site complexity. Inflation is not a single uniform rate across all cost categories. A nominal cash-flow model should use nominal rates consistently. A real model should use real rates consistently. Mixing a nominal discount rate with real costs can understate a provision.

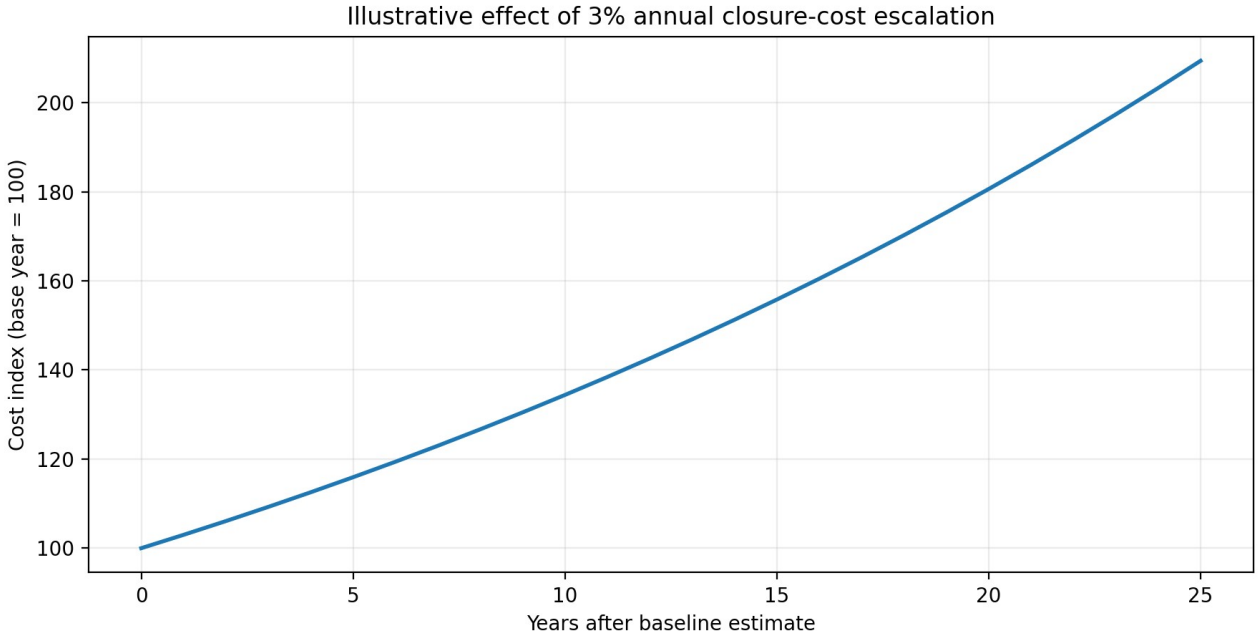


Figure 2. A hypothetical cost index rising 3% annually from a base of 100. The series illustrates compounding only.

In the illustrative chart, a cost index of 100 becomes approximately 209 after 25 years under 3% annual escalation. No claim is made that mining closure costs will increase at this rate. The example demonstrates why static unit costs require review when obligations are decades away. Independent estimation should separate general inflation from sector-specific escalation and site-driven scope growth.

The public-risk waterfall

A closure estimate should distinguish direct work from project management, contingency and long-term obligations. It should then distinguish the estimated obligation from the funds legally accessible after default. The resulting shortfall is a potential public exposure, not automatically a realised fiscal cost. The size of the shortfall depends on the scenario, the enforceability of guarantees and the performance of remaining assets.

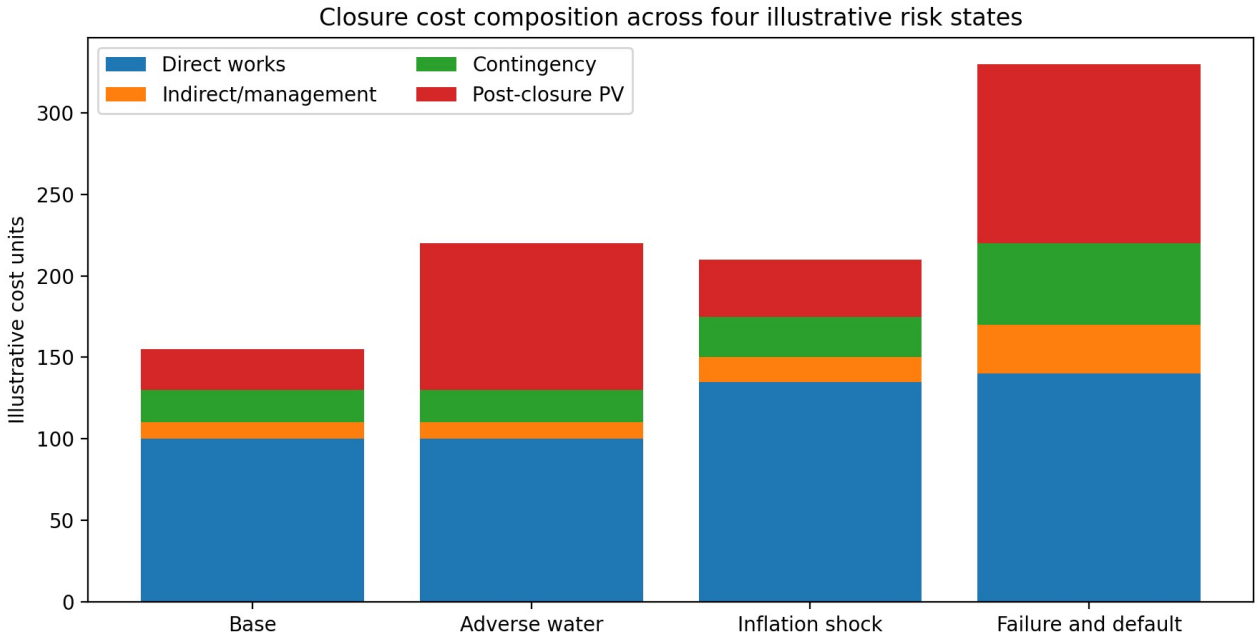


Figure 3. Illustrative cost components under four hypothetical risk states. Values are arbitrary cost units, not empirical observations.

The correct waterfall begins with the full contractor-executed closure cost, adds long-tail obligations and scenario contingencies, then subtracts only accessible and enforceable security and realistic recoveries. A bank guarantee that cannot be called on time should not be treated as equivalent to cash. An uncommitted parent support letter should not be treated as a funded trust. An asset sale value should not be credited without a buyer, legal authority and realistic transaction cost.

Financial instrument design and default testing

1. Cash collateral

High immediate liquidity if legally segregated, but capital intensive for the operator.

The core due-diligence test is not face value alone. The reviewer should examine custody, currency, access restrictions, interest ownership and bankruptcy remoteness. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: The balance is held in an account subject to competing claims. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

Author proposition: document a drawdown rehearsal, a counterparty-concentration test, a stress scenario and a responsible officer for each instrument. This converts financial assurance from a certificate in a file into an operationally executable protection.

Review question	Required evidence
Accessible after default?	Legal instrument and verified claims procedure
Adequate under downside case?	Scenario-adjusted estimate and independent review
Renewable or permanent?	Maturity schedule, renewal trigger and replacement plan
Independent of operator?	Custody, segregation and insolvency analysis

2. Bank letter of credit

A bank commitment may support prompt payment without full cash deposit.

The core due-diligence test is not face value alone. The reviewer should examine issuer rating, evergreen terms, jurisdiction, draw conditions, concentration and expiry. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: The instrument expires during a protracted insolvency or is disputed at draw. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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3. Surety bond

Third-party surety may reduce initial collateral needs and provide risk screening.

The core due-diligence test is not face value alone. The reviewer should examine coverage wording, cancellation rights, surety capacity, claims procedure and renewal. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: The bond excludes an obligation the regulator expected to be covered. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

Author proposition: document a drawdown rehearsal, a counterparty-concentration test, a stress scenario and a responsible officer for each instrument. This converts financial assurance from a certificate in a file into an operationally executable protection.

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4. Parent guarantee

Group credit can support a subsidiary but remains exposed to group distress.

The core due-diligence test is not face value alone. The reviewer should examine parent solvency, enforceability, governing law, priority and change of control. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: The group becomes insolvent alongside the operating subsidiary. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

Author proposition: document a drawdown rehearsal, a counterparty-concentration test, a stress scenario and a responsible officer for each instrument. This converts financial assurance from a certificate in a file into an operationally executable protection.

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Independent of operator?	Custody, segregation and insolvency analysis

5. Dedicated trust

Ring-fenced investment assets may fund post-closure services over time.

The core due-diligence test is not face value alone. The reviewer should examine trustee independence, investment policy, fees, draw rules and downside reserves. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: Poor returns or unanticipated capital replacement exhaust the trust. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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Independent of operator?	Custody, segregation and insolvency analysis

6. Pooled rehabilitation fund

A statutory pool can support specified abandoned-site costs across operators.

The core due-diligence test is not face value alone. The reviewer should examine eligible claims, contribution risk rating, accumulation target and moral hazard. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: A systemic downturn creates simultaneous claims exceeding available reserves. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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Independent of operator?	Custody, segregation and insolvency analysis

7. Insurance contract

Coverage may transfer defined insurable events but not every predictable closure duty.

The core due-diligence test is not face value alone. The reviewer should examine exclusions, limits, claims-made terms, insurer solvency and policy period. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: The relevant long-tail loss falls outside policy wording. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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Independent of operator?	Custody, segregation and insolvency analysis

8. Hybrid assurance package

Cash, surety, bank support and trusts can match different time horizons.

The core due-diligence test is not face value alone. The reviewer should examine no gaps or double counting, legal priority, escalation triggers and coordinated claims. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: Each provider assumes another instrument covers a contested obligation. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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Independent of operator?	Custody, segregation and insolvency analysis

9. Operator self-funding

Operating cash flow can finance progressive rehabilitation but is not protection after default.

The core due-diligence test is not face value alone. The reviewer should examine cash generation, capital allocation, reserve policies and ring-fencing. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: Commodity-price collapse removes the funding source before closure. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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Renewable or permanent?	Maturity schedule, renewal trigger and replacement plan
Independent of operator?	Custody, segregation and insolvency analysis

10. Public legacy programme

Public remediation funding can address historical orphaned sites where no responsible party remains.

The core due-diligence test is not face value alone. The reviewer should examine prioritisation, budget continuity, procurement, data quality and accountability. The appropriate instrument depends on the legal regime, the timing of work, the counterparty and the potential need for immediate emergency action.

Adverse case: Programme funds are spread thinly across low-priority sites while severe hazards persist. A credible contract or statutory arrangement should specify remedies before the adverse case arises. For long-tail obligations, renewal and replacement risk must be managed independently of initial issuance.

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The interaction between progressive rehabilitation and assurance

Progressive rehabilitation can reduce outstanding liability when work is complete, technically effective and accepted by the regulator. It should not reduce the bond merely because expenditure occurred. A planted slope, for example, may need several seasons of evidence before the risk of failure is materially lower. This principle supports responsible operators by allowing evidence-based reductions without transferring premature risk to the public.

A credible programme maps each rehabilitated unit to location, design, construction record, success criterion, monitoring period and release authority. The reduction in financial security should be linked to residual contractor cost, not to the amount already spent. Poorly executed work can require more expenditure than an undisturbed area, making spend-based reductions misleading.

British Columbia explicitly notes that progressive reclamation may decrease liability while new disturbance may increase it. Queensland uses estimated rehabilitation costs and risk assessments within its financial provisioning architecture. These are jurisdiction-specific mechanisms, not universal requirements. [R02] [R05]

Part III. Comparative jurisdiction studies

The following cases are descriptive. They compare statutory coverage, institutional design and documented implementation issues. No jurisdiction is ranked. The evidence is date-specific and should not be read as a current legal opinion for a particular project.

1. British Columbia, Canada

INSTITUTIONAL MODEL

Site-specific reclamation securities with regulator-determined form and amount. The province links security to outstanding liability and environmental and closure obligations. [R02] [R03] [R40]

DOCUMENTED EVIDENCE

As of 31 March 2024, the province reported C$4.97 billion secured against C$5.40 billion in known major-mine liability, an 8% gap. The measurement is historical and jurisdiction-specific. [R02] [R03] [R40]

STATUS AND SCOPE

The province introduced annual reclamation reporting changes in 2026, including MineSpace submissions and geospatial standards.

ANALYTICAL INTERPRETATION

The useful analytical distinction is between transparent liability estimates, security actually held, and the pace at which the difference is reduced.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

The fiscal dimension should be tested separately. A government may have a large aggregate guarantee register but limited cash to act immediately, or a pooled fund with substantial liquidity but statutory restrictions on eligible expenditures. The appropriate test is whether the financial architecture remains executable when several operators default in the same commodity downturn.

The social dimension is also distinct. Closure planning should specify which obligations are enforceable, which investments are discretionary, and which public agencies will sustain essential services after the mine exits. A large environmental bond is not evidence of a funded workforce or municipal transition programme.

Comparison axis	Question for the case
Coverage	Which closure and post-closure obligations are included?
Instrument	Who holds the funds, and what triggers a call?
Updating	How often do estimates and securities change?
Default	Who can commission works if the operator fails?
Release	What independent evidence supports partial or final release?

Transferability boundary: institutional design depends on legal authority, administrative capacity, financial-market depth, geology, mine scale and social context. A mechanism suited to one jurisdiction may require substantial adaptation elsewhere.

2. Queensland, Australia

INSTITUTIONAL MODEL

The Financial Provisioning Scheme established under 2018 legislation commenced in April 2019. It combines risk-based contributions and sureties, with provisions for a fund and residual risks. [R05] [R06] [R27]

DOCUMENTED EVIDENCE

The 2023-24 report recorded an aggregate estimated rehabilitation cost of A$13.73 billion at 30 June 2024, a fund balance of A$276.7 million and A$7.794 billion in surety. These are different accounting objects and should not be simply summed as complete coverage. [R05] [R06] [R27]

STATUS AND SCOPE

Changes effective in October 2025 modified risk categories and thresholds. A scheme review consultation closed 30 September 2026 with a final report expected for consideration in 2027.

ANALYTICAL INTERPRETATION

The Queensland case shows how financial risk classification, pooled resources and site-specific sureties can coexist. It also shows why scheme reforms require monitoring rather than immediate declarations of success.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

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3. Western Australia, Australia

INSTITUTIONAL MODEL

The Mining Rehabilitation Fund is a pooled levy-based mechanism introduced in 2013 for eligible tenement holders. It supports specified abandoned mine remediation. [R04] [R32]

DOCUMENTED EVIDENCE

The 2024-25 report recorded A$51.6 million in assessed levies, an increase of 8.17% over the previous year. This is levy assessment, not total liability or fund sufficiency. [R04] [R32]

STATUS AND SCOPE

A statutory ten-year review considered scheme effectiveness and opportunities for improvement.

ANALYTICAL INTERPRETATION

The case highlights the distinction between a pooled public-risk mechanism and a site-specific full-cost guarantee. Contribution adequacy depends on eligible claims, site inventory and loss distribution.

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4. United States federal hardrock mining

INSTITUTIONAL MODEL

Federal oversight differs across agencies and land regimes. GAO reviews show how monitoring information and site-level aggregation affect financial-assurance assessment. [R01] [R16] [R17] [R29]

DOCUMENTED EVIDENCE

GAO reported that, as of October 2017, BLM held more than US$3 billion in assurance, around US$11 million below estimated reclamation costs. The Forest Service held US$251 million as of November 2018 but lacked central information needed to judge sufficiency. [R01] [R16] [R17] [R29]

STATUS AND SCOPE

A 2025 USGS fact sheet and 2026 USMIN programme describe efforts to inventory abandoned mine features, explicitly distinguishing features from mine sites.

ANALYTICAL INTERPRETATION

The case illustrates that a financial number without an auditable, site-specific data system does not create complete regulatory control.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

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Transferability boundary: institutional design depends on legal authority, administrative capacity, financial-market depth, geology, mine scale and social context. A mechanism suited to one jurisdiction may require substantial adaptation elsewhere.

5. Chile

INSTITUTIONAL MODEL

Law No. 20,551 makes mine closure part of the life cycle and requires progressive planning and measures supporting physical and chemical stability. [R07] [R08]

DOCUMENTED EVIDENCE

SERNAGEOMIN publishes detailed guides for different mine sizes, temporary closure, partial closure, financial guarantees and audits. [R07] [R08]

STATUS AND SCOPE

The legal model links closure planning with operating phases rather than treating closure as a terminal application.

ANALYTICAL INTERPRETATION

Transferable lesson: define closure duties and financial mechanisms early, while allowing technical updates and proportionate procedures.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level

adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

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Transferability boundary: institutional design depends on legal authority, administrative capacity, financial-market depth, geology, mine scale and social context. A mechanism suited to one jurisdiction may require substantial adaptation elsewhere.

6. Peru

INSTITUTIONAL MODEL

Law No. 28090 governs mine closure plans and associated environmental guarantees. The 2025 official compilation describes updates, progressive-closure guarantee requirements and semiannual reporting. [R09]

DOCUMENTED EVIDENCE

Decree No. 006-2025-EM, dated 19 March 2025, is cited in the official 2025 edition. [R09]

STATUS AND SCOPE

The legal architecture links closure planning, monitoring, guarantee obligations and agency coordination.

ANALYTICAL INTERPRETATION

The case demonstrates why legal analysis must distinguish statutory requirements, implementing regulations and site-specific approved plans.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

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7. European Union

INSTITUTIONAL MODEL

The Extractive Waste Directive establishes requirements for extractive-waste management, closure planning and financial guarantees for covered waste facilities. [R10]

DOCUMENTED EVIDENCE

The European Commission guidance addresses calculation and periodic adjustment of guarantees and post-closure monitoring. [R10]

STATUS AND SCOPE

The regime concerns extractive-waste facilities and should not be misdescribed as one uniform full-mine bond for every activity in every member state.

ANALYTICAL INTERPRETATION

Transferable lesson: define the scope of the guarantee precisely and keep waste-facility obligations visible in the wider mine-closure budget.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

The fiscal dimension should be tested separately. A government may have a large aggregate guarantee register but limited cash to act immediately, or a pooled fund with substantial liquidity but statutory restrictions on eligible expenditures. The appropriate test is whether the financial architecture remains executable when several operators default in the same commodity downturn.

The social dimension is also distinct. Closure planning should specify which obligations are enforceable, which investments are discretionary, and which public agencies will sustain essential services after the mine exits. A large environmental bond is not evidence of a funded workforce or municipal transition programme.

Comparison axis	Question for the case
Coverage	Which closure and post-closure obligations are included?
Instrument	Who holds the funds, and what triggers a call?

Updating	How often do estimates and securities change?
Default	Who can commission works if the operator fails?
Release	What independent evidence supports partial or final release?

Transferability boundary: institutional design depends on legal authority, administrative capacity, financial-market depth, geology, mine scale and social context. A mechanism suited to one jurisdiction may require substantial adaptation elsewhere.

8. South Africa

INSTITUTIONAL MODEL

Financial provisioning for rehabilitation was transferred into the National Environmental Management Act framework through 2015 regulations. [R30]

DOCUMENTED EVIDENCE

Official 2024 communication describes an extension for certain pre-November-2015 rights holders pending finalisation of amendments. [R30]

STATUS AND SCOPE

The case highlights transition risk when revised requirements and compliance dates remain in motion.

ANALYTICAL INTERPRETATION

Analysts should verify current Gazette instruments and individual permit status before asserting a specific operator deadline.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

The fiscal dimension should be tested separately. A government may have a large aggregate guarantee register but limited cash to act immediately, or a pooled fund with substantial liquidity but statutory restrictions on eligible expenditures. The appropriate test is whether the financial architecture remains executable when several operators default in the same commodity downturn.

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Comparison axis	Question for the case
Coverage	Which closure and post-closure obligations are included?
Instrument	Who holds the funds, and what triggers a call?
Updating	How often do estimates and securities change?
Default	Who can commission works if the operator fails?
Release	What independent evidence supports partial or final release?

Transferability boundary: institutional design depends on legal authority, administrative capacity, financial-market depth, geology, mine scale and social context. A mechanism suited to one jurisdiction may require substantial adaptation elsewhere.

9. United Kingdom

INSTITUTIONAL MODEL

The Mining Remediation Authority manages legacy mining hazards and mine-water treatment, demonstrating how long-tail obligations become public service delivery. [R19] [R20]

DOCUMENTED EVIDENCE

Its 2025-26 performance report recorded 232 billion litres of mine-water treatment capacity created or maintained. The accounts reported mine-water provisions of GBP1.121 billion and public safety and subsidence provisions of GBP328 million as at 31 March 2026. [R19] [R20]

STATUS AND SCOPE

The auditor noted significant uncertainty in estimating the long-term liabilities, which depend on assumptions and future conditions.

ANALYTICAL INTERPRETATION

The case shows why post-closure treatment belongs in financial and institutional planning even when the original operator no longer exists.

A comparative review should not treat the nominal size of security as a complete performance indicator. The denominator may include different cost classes, and the numerator may include instruments with different liquidity and legal characteristics. A stronger assessment tests site-level adequacy, update frequency, independent costing, insolvency access, environmental performance, post-closure funding and conditions for release.

The fiscal dimension should be tested separately. A government may have a large aggregate guarantee register but limited cash to act immediately, or a pooled fund with substantial liquidity but statutory restrictions on eligible expenditures. The appropriate test is whether the financial architecture remains executable when several operators default in the same commodity downturn.

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Part IV. The CLOSURE Integrity Framework

The CLOSURE Integrity Framework is an author-developed diagnostic, not a statutory standard. Its seven pillars examine the chain from physical obligations to public release. A failure in one pillar cannot always be offset by strength elsewhere. For example, a large bond does not remedy a tailings

design failure, and technically sound rehabilitation does not guarantee liquidity after operator default.

Pillar	Primary test	Risk if neglected
C | Cost completeness	Does the estimate cover the full work and time horizon?	Underestimated liability
L | Liquidity and legal enforceability	Will funds be available after default?	Unfunded public intervention
O | Operational rehabilitation	Will physical and chemical systems remain stable?	Rework, contamination or hazard
S | Social transition	Are affected people and institutions prepared?	Concentrated economic disruption
U | Uncertainty and long-tail risk	Do assumptions survive adverse states?	Systematic underfunding
R | Regulatory independence	Is oversight competent and credible?	Unchallenged or unenforceable obligations
E | Evidence-based release	Does independent evidence support relinquishment?	Premature transfer of risk

The framework separates three layers. Layer one is a fatal-flaw screen for immediate safety, legality, insolvency access and rights concerns. Layer two is a 56-indicator maturity diagnostic. Layer three is a scenario-adjusted financing and implementation plan. No composite score should override a fatal flaw.

1. Cost completeness

Cost completeness is the foundation of financial integrity. Understating scope creates an artificial impression of affordability and may influence capital allocation, tax reporting, permit decisions and public expectations. The reviewer should begin with physical reality rather than a historical spreadsheet total.

1.1 Physical inventory

Diagnostic objective: Map all disturbed land, structures, wastes, water systems and access routes. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Geospatial inventory reconciled to permits and as-built plans. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Unmapped features or disputed ownership. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.2 Third-party execution

Diagnostic objective: Price works as if an independent contractor must mobilise after default. The reviewer should identify the exact duty, asset, time horizon and institution associated with this

control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Independent rates, mobilisation, demobilisation and supervision. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: In-house marginal rates used as the entire bond basis. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.3 Water and chemical scope

Diagnostic objective: Capture active and passive treatment, reagents, sludge and replacement plant. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Chemistry and flow models with annual cost schedule. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Treatment omitted or assumed to stop without evidence. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.4 Contingency

Diagnostic objective: Estimate scope and cost uncertainty by work package. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Documented probabilistic or risk-based contingency. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Uniform percentage with no risk rationale. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal

enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.5 Indirect costs

Diagnostic objective: Include management, permits, insurance, taxes where applicable and contractor risk. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Work breakdown structure with indirect-cost allocation. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Overhead or professional services omitted. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.6 Long-tail monitoring

Diagnostic objective: Fund monitoring, reporting and response after construction works. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Post-closure operating plan and duration assumptions. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: One-off closure estimate with no operating tail. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.7 Cost escalation

Diagnostic objective: Separate price inflation, sector escalation and quantity growth. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Cost index and update policy with real/nominal consistency. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Historic unit costs treated as permanently valid. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

1.8 Scope reconciliation

Diagnostic objective: Explain differences between engineering, accounting and regulatory numbers. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Signed reconciliation by engineering, finance and compliance. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Provision and security assumed equal without analysis. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Physical inventory	Map all disturbed land, structures, wastes, water systems and access routes	Geospatial inventory reconciled to permits and as-built plans
Third-party execution	Price works as if an independent contractor must mobilise after default	Independent rates, mobilisation, demobilisation and supervision
Water and chemical scope	Capture active and passive treatment, reagents, sludge and replacement plant	Chemistry and flow models with annual cost schedule
Contingency	Estimate scope and cost uncertainty by work package	Documented probabilistic or risk-based contingency

Indirect costs	Include management, permits, insurance, taxes where applicable and contractor risk	Work breakdown structure with indirect-cost allocation
Long-tail monitoring	Fund monitoring, reporting and response after construction works	Post-closure operating plan and duration assumptions
Cost escalation	Separate price inflation, sector escalation and quantity growth	Cost index and update policy with real/nominal consistency
Scope reconciliation	Explain differences between engineering, accounting and regulatory numbers	Signed reconciliation by engineering, finance and compliance

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

2. Liquidity and legal enforceability

A financial instrument protects the public only if it survives operator default and permits timely execution. Liquidity, issuer strength and legal rights must therefore be examined together. A high nominal face value is insufficient if access is delayed or contested.

2.1 Instrument custody

Diagnostic objective: Establish legal ownership and segregation of assurance assets. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Custody confirmation and insolvency legal opinion. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Assets remain subject to general creditors. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.2 Immediate call

Diagnostic objective: Demonstrate timely access to funds after a default event. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Tested call procedure and named authorised signatories. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Disputed or ambiguous trigger language. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.3 Issuer strength

Diagnostic objective: Assess bank, surety, insurer and guarantor credit exposure. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Counterparty ratings, limits and concentration dashboard. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Guarantee issued by financially linked distressed entity. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.4 Maturity coverage

Diagnostic objective: Prevent gaps at expiry or during licence transfer. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Renewal calendar and automatic replacement triggers. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Instrument lapses during insolvency or litigation. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.5 Currency matching

Diagnostic objective: Manage exchange risk between security and closure costs. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Currency sensitivity and hedge or reserve policy. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Security currency depreciates against imported costs. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.6 Claim hierarchy

Diagnostic objective: Define order of recourse across cash, surety and trusts. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Legal waterfall and no-double-counting reconciliation. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Multiple providers contest primary responsibility. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.7 Emergency funding

Diagnostic objective: Reserve immediate cash for pumping, treatment and safety. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Rapid-access liquidity test and emergency procurement plan. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Works wait for lengthy bond enforcement. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

2.8 Transfer continuity

Diagnostic objective: Keep security effective through sale, merger or restructuring. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Regulator consent and executed replacement instrument. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Parent support disappears at change of control. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Instrument custody	Establish legal ownership and segregation of assurance assets	Custody confirmation and insolvency legal opinion
Immediate call	Demonstrate timely access to funds after a default event	Tested call procedure and named authorised signatories
Issuer strength	Assess bank, surety, insurer and guarantor credit exposure	Counterparty ratings, limits and concentration dashboard
Maturity coverage	Prevent gaps at expiry or during licence transfer	Renewal calendar and automatic replacement triggers
Currency matching	Manage exchange risk between security and closure costs	Currency sensitivity and hedge or reserve policy
Claim hierarchy	Define order of recourse across cash, surety and trusts	Legal waterfall and no-double-counting reconciliation
Emergency funding	Reserve immediate cash for pumping, treatment and safety	Rapid-access liquidity test and emergency procurement plan
Transfer continuity	Keep security effective through sale, merger or restructuring	Regulator consent and executed replacement instrument

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next

action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

3. Operational rehabilitation

Closure should be designed into operations. Progressive works, stable tailings, water controls and final land use are operating disciplines that reduce future costs and uncertainty. The test is performance after the mine ceases to function as an integrated operating system.

3.1 Progressive works

Diagnostic objective: Complete and verify rehabilitation while productive cash flow exists. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Annual disturbed-versus-rehabilitated geospatial reconciliation. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Activity reported as success before ecological stability. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.2 Closure design basis

Diagnostic objective: Maintain integrated technical design for final landforms. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Approved design basis and independent review. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Closure design outdated after mine expansion. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.3 Tailings permanence

Diagnostic objective: Demonstrate geotechnical and hydrological safety post-closure. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Instrumentation, consequence analysis and GISTM-related evidence. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Monitoring ends while material failure modes persist. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.4 Water rebound

Diagnostic objective: Model groundwater and surface water after pumping stops. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Calibrated hydrogeological model and monitoring triggers. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: No contingency for changed water levels or chemistry. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.5 Plant decommissioning

Diagnostic objective: Safely remove hazardous materials and isolate utilities. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Hazard survey and contractor method statements. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Salvage assumptions substitute for safe dismantling. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.6 Land-use success

Diagnostic objective: Define measurable final land capability and access. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Reference sites, agreed end use and monitoring criteria. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Cosmetic vegetation used as proof of functional recovery. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.7 Climate resilience

Diagnostic objective: Stress-test structures and vegetation against changing hazards. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Flood, drought, wildfire and erosion sensitivity. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Design life inconsistent with long-term hazard exposure. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

3.8 Emergency response

Diagnostic objective: Maintain contingency capability through suspension and closure. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Response plans, funding and drills. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: No staff or resources during care and maintenance. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Progressive works	Complete and verify rehabilitation while productive cash flow exists	Annual disturbed-versus-rehabilitated geospatial reconciliation
Closure design basis	Maintain integrated technical design for final landforms	Approved design basis and independent review
Tailings permanence	Demonstrate geotechnical and hydrological safety post-closure	Instrumentation, consequence analysis and GISTM-related evidence
Water rebound	Model groundwater and surface water after pumping stops	Calibrated hydrogeological model and monitoring triggers
Plant decommissioning	Safely remove hazardous materials and isolate utilities	Hazard survey and contractor method statements
Land-use success	Define measurable final land capability and access	Reference sites, agreed end use and monitoring criteria
Climate resilience	Stress-test structures and vegetation against changing hazards	Flood, drought, wildfire and erosion sensitivity
Emergency response	Maintain contingency capability through suspension and closure	Response plans, funding and drills

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

4. Social transition

Mine closure redistributes economic opportunity and risk. Workers, contractors, households, rights holders and local governments need credible information and time to adapt. Social transition should be co-designed rather than treated as a final communications programme.

4.1 Affected population

Diagnostic objective: Identify workers, contractors, suppliers and communities at risk. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An

assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Disaggregated exposure baseline and consultation. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Social plan counts direct employees only. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.2 Early participation

Diagnostic objective: Begin participatory planning before terminal mine years. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Documented engagement process and response record. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Consultation begins after closure decision is final. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.3 Employment pathways

Diagnostic objective: Link retraining to real labour-market demand. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Placement outcomes and employer agreements. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Training counts presented as durable employment. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or

legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.4 Supplier transition

Diagnostic objective: Reduce single-buyer exposure for local firms. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Supplier concentration and diversification indicators. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Procurement success hides closure vulnerability. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.5 Public services

Diagnostic objective: Plan transfer or continuation of mine-supported services. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Municipal budget and service transition agreements. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Community inherits unaffordable infrastructure. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.6 Rights and culture

Diagnostic objective: Respect tenure, heritage and participation rights. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Legal review, rights-holder engagement and agreements. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Technical closure ignores land-use disputes. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.7 Health and safety

Diagnostic objective: Provide risk communication and exposure-based monitoring. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Independent testing, referral and grievance mechanisms. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Unfunded promises of long-term health surveillance. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

4.8 Distributional equity

Diagnostic objective: Assess who receives benefits and who bears residual costs. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Gender, income and geography impact analysis. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Average outcomes conceal concentrated losses. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Affected population	Identify workers, contractors, suppliers and communities at risk	Disaggregated exposure baseline and consultation
Early participation	Begin participatory planning before terminal mine years	Documented engagement process and response record
Employment pathways	Link retraining to real labour-market demand	Placement outcomes and employer agreements
Supplier transition	Reduce single-buyer exposure for local firms	Supplier concentration and diversification indicators
Public services	Plan transfer or continuation of mine-supported services	Municipal budget and service transition agreements
Rights and culture	Respect tenure, heritage and participation rights	Legal review, rights-holder engagement and agreements
Health and safety	Provide risk communication and exposure-based monitoring	Independent testing, referral and grievance mechanisms
Distributional equity	Assess who receives benefits and who bears residual costs	Gender, income and geography impact analysis

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

5. Uncertainty and long-tail risk

Closure forecasts combine uncertain scope, future prices, environmental processes and discount assumptions. A single point estimate hides these risks. Stress testing should reveal which assumptions drive the largest changes in funding need.

5.1 Scenario completeness

Diagnostic objective: Test more than a single central closure estimate. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Defined low, base and severe cases. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Assurance calibrated only to best-case assumptions. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.2 Treatment duration

Diagnostic objective: Assess finite, extended and perpetual treatment proxies. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Hydrochemical evidence and sensitivity model. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Arbitrary treatment end date. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.3 Discount discipline

Diagnostic objective: Use consistent real/nominal assumptions and conservative returns. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Discount-rate disclosure and stress test. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Optimistic return assumptions reduce required trust capital. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.4 Capital replacement

Diagnostic objective: Budget plant, pumps and infrastructure renewal. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Asset lifecycle and replacement reserve. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Perpetuity model includes OPEX but not replacement CAPEX. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.5 Climate shocks

Diagnostic objective: Account for flood, drought, fire and erosion variability. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Hazard screening and adaptive trigger levels. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Historic conditions treated as permanent. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.6 Commodity stress

Diagnostic objective: Test simultaneous defaults during low-price cycles. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Portfolio stress and correlated default assumptions. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Pooled fund models independent defaults only. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.7 Data uncertainty

Diagnostic objective: Record missing, low-confidence and contradictory evidence. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Confidence grading and independent verification. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Unknowns converted into zero-cost assumptions. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

5.8 Model governance

Diagnostic objective: Version, challenge and periodically recalibrate estimates. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Model owner, audit trail and independent review. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Unreviewed spreadsheet becomes a permanent policy. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Scenario completeness	Test more than a single central closure estimate	Defined low, base and severe cases
Treatment duration	Assess finite, extended and perpetual treatment proxies	Hydrochemical evidence and sensitivity model

Discount discipline	Use consistent real/nominal assumptions and conservative returns	Discount-rate disclosure and stress test
Capital replacement	Budget plant, pumps and infrastructure renewal	Asset lifecycle and replacement reserve
Climate shocks	Account for flood, drought, fire and erosion variability	Hazard screening and adaptive trigger levels
Commodity stress	Test simultaneous defaults during low-price cycles	Portfolio stress and correlated default assumptions
Data uncertainty	Record missing, low-confidence and contradictory evidence	Confidence grading and independent verification
Model governance	Version, challenge and periodically recalibrate estimates	Model owner, audit trail and independent review

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

6. Regulatory independence

Assurance quality depends on competent, well-resourced institutions. Oversight needs independent technical judgement, auditable data and legal authority to enforce obligations. Data fragmentation can be as consequential as an inadequate bond.

6.1 Decision separation

Diagnostic objective: Separate technical approval, custody and security release. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Mandate map and segregation of duties. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Single official controls estimates and release without review. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.2 Data systems

Diagnostic objective: Maintain searchable, site-level liability and assurance records. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Digital register with geospatial linkages. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Paper files prevent aggregate oversight. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.3 Update discipline

Diagnostic objective: Review security after disturbance, cost or risk changes. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Annual and event-driven update protocol. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Bond unchanged after major mine expansion. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.4 Independent assurance

Diagnostic objective: Use qualified external technical and financial review. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Conflict-of-interest checks and signed opinions. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Operator estimate accepted without challenge. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.5 Enforcement capacity

Diagnostic objective: Maintain staff, legal powers and procurement routes. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Resourcing plan and tested enforcement procedure. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Regulator unable to act despite a formal bond. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.6 Transparency

Diagnostic objective: Publish comparable information with legitimate redactions. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Public summary of liability, security and release status. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Public sees only aggregate fund totals. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.7 Cross-agency alignment

Diagnostic objective: Coordinate mining, environment, water and finance roles. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Decision-rights map and escalation forum. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Conflicting permits leave duties unassigned. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

6.8 Institutional continuity

Diagnostic objective: Protect records and duties through personnel or government changes. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Records retention and succession protocols. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Knowledge disappears when staff depart. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Decision separation	Separate technical approval, custody and security release	Mandate map and segregation of duties
Data systems	Maintain searchable, site-level liability and assurance records	Digital register with geospatial linkages
Update discipline	Review security after disturbance, cost or risk changes	Annual and event-driven update protocol
Independent assurance	Use qualified external technical and financial review	Conflict-of-interest checks and signed opinions
Enforcement capacity	Maintain staff, legal powers and procurement routes	Resourcing plan and tested enforcement procedure
Transparency	Publish comparable information with legitimate redactions	Public summary of liability, security and release status
Cross-agency alignment	Coordinate mining, environment, water and finance roles	Decision-rights map and escalation forum
Institutional continuity	Protect records and duties through personnel or government changes	Records retention and succession protocols

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next

action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

7. Evidence-based release

Final release is a transfer of risk. It should be supported by durable environmental and social performance, legally effective transfer arrangements and an explicit residual-risk plan. Completion of construction is not the same as proof of long-term stability.

7.1 Completion evidence

Diagnostic objective: Require as-built records and independent verification. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Completion certificates and test results. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Release based on expenditure reports alone. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.2 Performance period

Diagnostic objective: Observe rehabilitation through meaningful seasons and events. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Time-series monitoring against thresholds. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Bond released after one favourable observation. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.3 Residual risk

Diagnostic objective: Identify remaining obligations and finance them explicitly. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Residual-risk register and funding instrument. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Residual liabilities become unfunded public duties. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.4 Receiving entity

Diagnostic objective: Confirm successor capacity and legal acceptance. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Transfer agreement, budget and asset condition. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Infrastructure transferred without maintenance finance. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.5 Rights closure

Diagnostic objective: Resolve agreements, grievances and access duties. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Consultation records and dispute-resolution status. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Outstanding community claims ignored. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for

independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.6 Reopening triggers

Diagnostic objective: Define response when new evidence changes risk. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Legal and technical reopener conditions. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: No remedy after unexpected contamination emerges. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.7 Public disclosure

Diagnostic objective: Explain why security was reduced or released. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Published evidence summary and decision rationale. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Release occurs without a visible evidentiary basis. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

7.8 Long-term archive

Diagnostic objective: Preserve models, sampling and design records. The reviewer should identify the exact duty, asset, time horizon and institution associated with this control. An assertion of compliance is weaker than a dated record showing implementation and measured performance.

Evidence test: Permanent data custodian and open-format archive. Documents should be traceable to the underlying site, permit, period and responsible professional. Where information is missing, the control should be marked unknown rather than scored as satisfactory. Uncertainty should influence contingency or trigger further investigation.

Failure signal: Future regulators cannot reconstruct the closure basis. The corrective action should specify an accountable owner, a deadline, the cash or engineering resources required, and a condition for independent closure of the issue. Where the signal relates to immediate public safety or legal enforceability, the project should receive a fatal-flaw review rather than relying on an aggregate maturity score.

Measurement guidance: assign 0 where the control is absent or unverified, 1 for a documented intention, 2 for partial design, 3 for an implemented process, 4 for repeated performance evidence, and 5 for independently assured performance. These anchors are author propositions for internal diagnosis. They do not constitute certification or a jurisdictional ranking.

Indicator	Evidence focus	Failure test
Completion evidence	Require as-built records and independent verification	Completion certificates and test results
Performance period	Observe rehabilitation through meaningful seasons and events	Time-series monitoring against thresholds
Residual risk	Identify remaining obligations and finance them explicitly	Residual-risk register and funding instrument
Receiving entity	Confirm successor capacity and legal acceptance	Transfer agreement, budget and asset condition
Rights closure	Resolve agreements, grievances and access duties	Consultation records and dispute-resolution status
Reopening triggers	Define response when new evidence changes risk	Legal and technical reopener conditions
Public disclosure	Explain why security was reduced or released	Published evidence summary and decision rationale
Long-term archive	Preserve models, sampling and design records	Permanent data custodian and open-format archive

Pillar interpretation: the eight indicators are related but not interchangeable. A mature system documents why each control matters, identifies its own weakest assumption and assigns the next action. Any proposed overall score should be accompanied by the underlying indicator evidence and fatal-flaw register.

Part V. Twelve stress scenarios for closure finance and governance

These scenarios are hypothetical and designed for decision testing. They do not predict a specific mine failure or commodity outcome. The same shock can affect technical, financial and social obligations differently. A sound assurance programme identifies the first failure point and funds an executable response.

Scenario 01: Commodity collapse and simultaneous defaults

TRIGGER AND CAUSAL PATHWAY

A prolonged fall in mineral prices weakens operator cash flow, causes care-and-maintenance decisions and increases correlated insolvency risk.

FINANCIAL TRANSMISSION

Bank and surety exposure can rise while public rehabilitation funds face several claims in the same period.

COMMUNITY AND INSTITUTIONAL EFFECT

Workers and suppliers lose income before final environmental works are financed.

RESPONSE DESIGN

Stress test correlated default, immediate water-treatment cash, instrument expiry and regulator procurement capacity.

EARLY WARNING DATA

Spot and forward prices, operator liquidity, issuer concentration, arrears, rehabilitation progress.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 02: Unexpected acid generation

TRIGGER AND CAUSAL PATHWAY

New geochemical evidence reveals higher contaminant loading than the approved closure model anticipated.

FINANCIAL TRANSMISSION

Long-term treatment CAPEX and OPEX increase, and the required trust balance changes sharply with discount assumptions.

COMMUNITY AND INSTITUTIONAL EFFECT

Water users and downstream communities face uncertainty and may demand independent sampling.

RESPONSE DESIGN

Recalibrate the mass balance, test passive alternatives, fund emergency treatment and update the assurance.

EARLY WARNING DATA

Water quality, flow, oxidation indicators, treatment performance, replacement cost and regulatory thresholds.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

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Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
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Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 03: Tailings instability after closure

TRIGGER AND CAUSAL PATHWAY

A closed tailings facility shows deformation, seepage or erosion beyond design thresholds.

FINANCIAL TRANSMISSION

Emergency engineering, drainage, monitoring and remediation may exceed a routine maintenance provision.

COMMUNITY AND INSTITUTIONAL EFFECT

Downstream residents face physical safety and livelihood concerns even before a failure occurs.

RESPONSE DESIGN

Escalate through engineer-of-record and independent review, restrict access and secure emergency finance.

EARLY WARNING DATA

Inclinometers, piezometers, seepage chemistry, rainfall, visual inspection and consequence maps.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

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Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 04: Extreme rainfall and flood

TRIGGER AND CAUSAL PATHWAY

A high-consequence rainfall event damages drainage, covers or access routes after operations cease.

FINANCIAL TRANSMISSION

Unplanned repair costs rise while insurance and guarantee coverage may be disputed.

COMMUNITY AND INSTITUTIONAL EFFECT

Road access, water supply and downstream livelihoods can be affected.

RESPONSE DESIGN

Test design exceedance, emergency mobilisation, redundant access and adaptive closure standards.

EARLY WARNING DATA

Rainfall intensity, freeboard, erosion, water levels, asset condition and response time.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should

therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 05: Care and maintenance becomes indefinite

TRIGGER AND CAUSAL PATHWAY

A temporary suspension extends across multiple years without a credible restart or final closure decision.

FINANCIAL TRANSMISSION

Security may be calibrated to a future closure date while essential pumping and security costs arise immediately.

COMMUNITY AND INSTITUTIONAL EFFECT

Uncertain employment and service continuity undermines transition planning.

RESPONSE DESIGN

Establish suspension triggers, minimum operating cash and mandatory re-estimation intervals.

EARLY WARNING DATA

Care-and-maintenance cash runway, water balance, staffing, site incidents and commodity sensitivity.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 06: Corporate sale to a weaker operator

TRIGGER AND CAUSAL PATHWAY

Ownership transfers to an entity with limited capital and different risk appetite.

FINANCIAL TRANSMISSION

Parent guarantees, collateral arrangements and legal recourse may change before the regulator updates security.

COMMUNITY AND INSTITUTIONAL EFFECT

Community commitments and local supplier obligations risk fragmentation.

RESPONSE DESIGN

Require executed replacement instruments and a verified obligation register before licence transfer.

EARLY WARNING DATA

Beneficial ownership, audited solvency, transfer terms, guarantee expiry and agreement continuity.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 07: Discount-rate reversal

TRIGGER AND CAUSAL PATHWAY

A long-term trust model is recalculated with a lower sustainable real return.

FINANCIAL TRANSMISSION

Required principal rises materially, especially for near-perpetual treatment obligations.

COMMUNITY AND INSTITUTIONAL EFFECT

The funding gap may constrain future community or environmental expenditure.

RESPONSE DESIGN

Use multiple real-rate cases, conservative investment policy and replenishment triggers.

EARLY WARNING DATA

Net real return, fees, duration, capital replacement, liquidity and actuarial review.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 08: Contractor inflation and market scarcity

TRIGGER AND CAUSAL PATHWAY

Several large mines close in one region while specialist contractors and equipment are scarce.

FINANCIAL TRANSMISSION

Unit rates, mobilisation time and contingency rise together.

COMMUNITY AND INSTITUTIONAL EFFECT

Rehabilitation delays extend exposure and employment losses.

RESPONSE DESIGN

Procure framework capacity early, stress-test unit rates and prioritise high-consequence works.

EARLY WARNING DATA

Contractor quotes, wage indices, equipment availability, backlog and mobilisation lead time.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 09: Public fund stress

TRIGGER AND CAUSAL PATHWAY

A pooled scheme experiences more or larger claims than its actuarial assumptions anticipated.

FINANCIAL TRANSMISSION

Liquid assets and long-term investment returns may not match the timing of remediation obligations.

COMMUNITY AND INSTITUTIONAL EFFECT

Public confidence declines if high-risk sites remain untreated.

RESPONSE DESIGN

Publish risk-based adequacy tests, contribution sensitivity and prioritisation criteria.

EARLY WARNING DATA

Fund balance, claims pipeline, correlated exposures, investment liquidity and statutory coverage.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 10: Failed post-mining redevelopment

TRIGGER AND CAUSAL PATHWAY

A proposed industrial, tourism or renewable reuse project loses its buyer or finance after security was reduced.

FINANCIAL TRANSMISSION

Demolition and environmental duties return without the anticipated salvage or transfer proceeds.

COMMUNITY AND INSTITUTIONAL EFFECT

Community expectations of replacement jobs and services are disappointed.

RESPONSE DESIGN

Do not credit speculative reuse until permits, finance, receiving entity and liabilities are enforceable.

EARLY WARNING DATA

Executed agreements, financing, demand studies, remediation certificates and maintenance budget.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but

their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 11: Data loss and institutional discontinuity

TRIGGER AND CAUSAL PATHWAY

Technical staff leave and historical mine records become inaccessible or obsolete.

FINANCIAL TRANSMISSION

New investigations, duplicated sampling and uncertainty contingencies increase.

COMMUNITY AND INSTITUTIONAL EFFECT

Communities struggle to obtain credible information about residual risks.

RESPONSE DESIGN

Require permanent digital archives, open formats, legal custody and independent records checks.

EARLY WARNING DATA

As-built plans, sample databases, model versions, inspection logs, permit history and transfer records.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

CLOSURE test	Scenario question
Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Scenario 12: Delayed relinquishment

TRIGGER AND CAUSAL PATHWAY

Physical works finish, but post-closure monitoring does not demonstrate agreed success criteria.

FINANCIAL TRANSMISSION

Security remains tied up and monitoring costs continue, affecting both operator liquidity and public risk.

COMMUNITY AND INSTITUTIONAL EFFECT

Future land use and community planning remain uncertain.

RESPONSE DESIGN

Use staged release tied to evidence and clearly define residual-risk financing and reopener conditions.

EARLY WARNING DATA

Success metrics, multi-season trends, independent audits, legal transfer and public disclosure.

The board should compare the central estimate with a downside funding requirement that includes contractor mobilisation, legal execution time, temporary controls and long-tail environmental services. The regulator should identify which funds are callable within days, which require claims adjudication, and which are dependent on future investment returns. This prevents a nominally adequate guarantee from being mistaken for an emergency operating budget.

A complete scenario test also asks whether the responsible institution has sufficient authority, staff, records and procurement arrangements to commission the work. If the operator disappears, a technical plan with no executing organisation is not a credible remedy. The scenario owner should therefore name the implementing entity and demonstrate the legal route to site access and expenditure.

For social transition, assess the timing of job loss, supplier payments, public-service disruption and communication. Environmental security and social-transition funding should not be conflated, but their interaction should be visible in the integrated closure plan. A technically stable site can still produce concentrated hardship if households and institutions lack time to adapt.

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Cost	What new work or extended duration arises?
Liquidity	Which funds are available immediately?
Operations	What technical controls prevent escalation?
Social	Who bears the earliest losses?
Uncertainty	Which assumptions fail together?
Regulation	Who has legal authority to intervene?
Evidence	What observation ends the emergency phase?

Part VI. Policy architecture and implementation options

The following policy options are presented as analytical choices, not political endorsements. Their effectiveness depends on institutional capacity, legal context, fiscal exposure and the risk profile of the mine portfolio. Each option has benefits, costs and implementation conditions. Governments and stakeholders retain responsibility for their own decisions.

Policy option 01: Full-cost third-party estimation

Instrument design: Require contractor-executed closure estimates with indirect costs and post-closure obligations.

Potential benefit: Improves comparability between operator default and funded work. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Higher upfront security can affect project finance, especially for smaller operators. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Independent cost guidance, qualified estimators, data access and appeal process. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 02: Risk-rated assurance contributions

Instrument design: Set fund contributions or instrument requirements using defined risk categories.

Potential benefit: Links cost of security to credit and environmental risk. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Opaque models can create disputes or inaccurate incentives. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Published methodology, independent review and periodic recalibration. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?

Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 03: Staged progressive-rehabilitation release

Instrument design: Permit reductions after verified physical and ecological performance.

Potential benefit: Rewards actual risk reduction and can release capital. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Premature release transfers later failures to the public. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Independent evidence, multi-season criteria and reopener clauses. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 04: Ring-fenced long-tail trusts

Instrument design: Fund treatment and monitoring through segregated assets with independent governance.

Potential benefit: Improves continuity after corporate exit. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Low real returns, investment fees and cost shocks can exhaust capital. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Conservative modelling, investment policy, reserves and trustee oversight. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 05: Central digital assurance registers

Instrument design: Publish site-level liabilities, security, status and review dates where legally permissible.

Potential benefit: Improves oversight and reduces data fragmentation. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Sensitive information and inconsistent definitions require safeguards. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Standard data model, audit trail, legal access and quality controls. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 06: Social-transition planning conditions

Instrument design: Require credible workforce, supplier and public-service transition processes.

Potential benefit: Improves preparedness and participation. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Mandates without finance or labour-market demand can become symbolic. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Early consultation, responsibilities, measurable outcomes and financing. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 07: Residual-risk funding mechanisms

Instrument design: Collect or secure funds for defined residual obligations after technical completion.

Potential benefit: Supports responsible relinquishment where risk persists. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Unclear boundaries may socialise avoidable operator costs. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Strict eligibility, quantified risks, transparency and independent release. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 08: Portfolio stress tests

Instrument design: Assess multiple mine defaults and correlated environmental shocks.

Potential benefit: Makes systemic risk visible to public finance authorities. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Models can create false precision without adequate data. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Scenario ranges, independent challenge and regular updating. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 09: Transfer and change-of-control safeguards

Instrument design: Condition licence transfers on continued financial and technical capacity.

Potential benefit: Reduces the risk of liabilities moving to weakly capitalised entities. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Overly rigid processes can impede legitimate transactions. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Clear thresholds, timely approvals and replacement guarantees. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

Policy option 10: Historic-mine risk inventories

Instrument design: Use geospatial inventories and consequence-based remediation priorities.

Potential benefit: Improves allocation of limited public remediation budgets. This benefit should be evaluated against a credible baseline rather than the existence of a new rule or programme. The relevant test is whether the instrument changes environmental performance, reduces public exposure or improves social-transition outcomes.

Potential cost or risk: Incomplete inventories and inconsistent site definitions can mislead. Fiscal, administrative and market effects should be assessed before adoption. A policy that reduces one category of risk may create another through weaker project finance, moral hazard, reduced competition or regulatory burden.

Implementation conditions: Standard hazard taxonomy, inspections and transparent prioritisation. The authority should define measurable outputs, a review period and an exit or adjustment mechanism. Consultation with affected parties should occur before obligations are finalised, and the legal instrument should identify responsible agencies.

Evidence standard: compare the number and quality of implemented controls, funded obligations and observed performance against the pre-policy state. A regulation in force is an institutional fact. An improvement in outcomes is a separate empirical claim requiring evidence.

Policy evaluation	Minimum question
Additionality	What changes compared with the counterfactual?
Distribution	Who pays, who benefits and who bears residual risk?
Enforceability	Which authority can compel performance?
Financial integrity	What is the public exposure under default?
Review	When and how will the option be reconsidered?

A six-stage implementation sequence

0-90 days: inventory and baseline

Reconcile permits, disturbed areas, mine plans, tailings, water, workforce, suppliers, financial statements and security instruments. Create a version-controlled liability register with source confidence and named data owners.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

90-180 days: independent cost and legal review

Commission a third-party closure estimate, verify quantity take-offs and contractor rates, review all instruments for enforceability and document accounting-to-assurance differences.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

180-270 days: scenario and community analysis

Stress-test commodity, climate, water, contractor and insolvency conditions. Map workforce and municipal exposure, engage affected communities and document competing land-use expectations.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

270-365 days: assurance redesign

Address security gaps, issuer concentration, expiry risk and long-tail funding. Prioritise high-consequence technical works and define progressive-rehabilitation milestones.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

Year 2-3: delivery and independent verification

Execute progressive works, update financial assurance annually and after material changes, report measurable ecological and social outcomes, and commission independent reviews.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

Year 4 onward: post-closure and relinquishment

Apply staged release only after performance evidence, fund residual risks, identify successor institutions and preserve the technical archive with enforceable reopener provisions.

Governance output: a signed decision log stating the owner, due date, evidence required, cash impact, legal authority, affected stakeholders and residual uncertainty. The programme should not report a milestone as complete until the corresponding evidence is available for independent inspection.

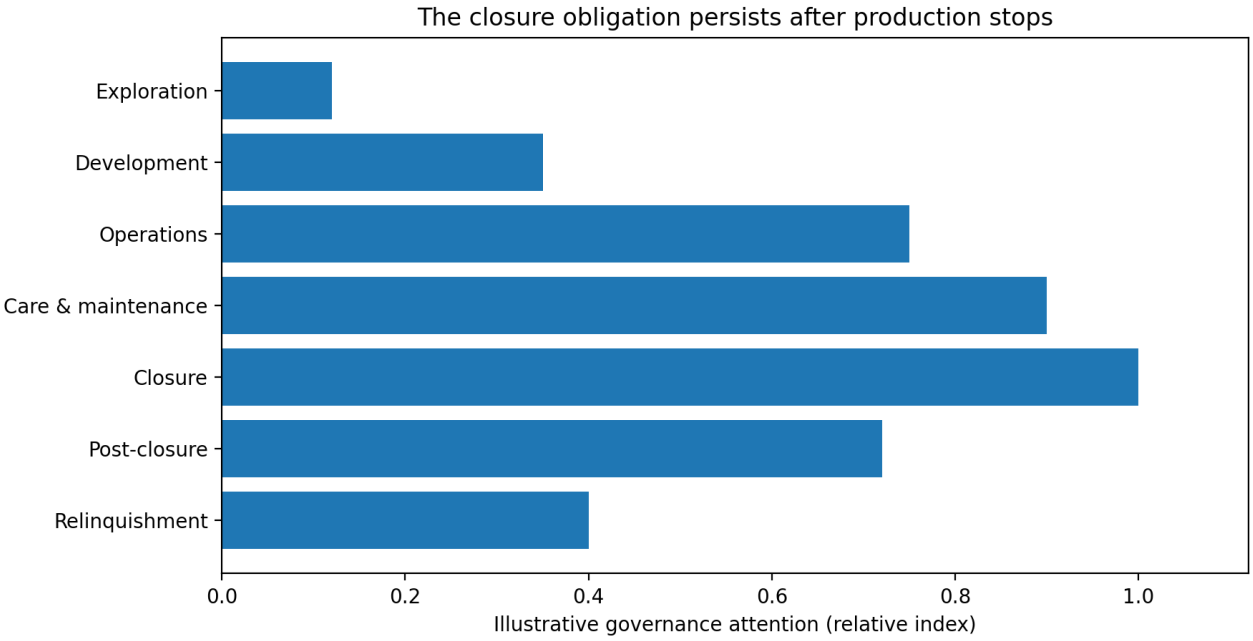


Figure 4. Illustrative governance-attention index by mine life-cycle phase. This is an author-developed conceptual illustration, not observed data.

Part VII. Board, regulator and investor decision protocols

Decision protocol 01: Capital allocation

Primary decision question: Has closure expenditure been integrated into mine design and capital approvals rather than deferred to the terminal years?

Accountability: Board capital committee and site technical team. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a

public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Closure estimate, project economics, funding schedule. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 02: Financial reporting

Primary decision question: Are provision assumptions, discount rates and changes reconciled with the regulatory bond?

Accountability: Audit committee and finance. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: IAS 37/IFRIC 1 accounting memorandum and bond reconciliation. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 03: Water permanence

Primary decision question: Which water-treatment duties extend beyond the current mine plan and who funds them?

Accountability: Environmental and technical assurance. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Hydrochemical model, treatment OPEX and long-tail trust. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 04: Tailings safety

Primary decision question: Are closure and post-closure stability conditions supported by independent engineering?

Accountability: Technical risk committee. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Design basis, independent review and monitoring thresholds. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer

Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 05: Corporate solvency

Primary decision question: Would the assurance remain accessible if the operator and parent failed simultaneously?

Accountability: Treasury and legal. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Instrument opinions, issuer concentration and draw rehearsal. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 06: Community transition

Primary decision question: What proportion of local jobs, suppliers and public services depends on the mine?

Accountability: Social performance and local government. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Exposure baseline, transition plan and participation record. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 07: Climate exposure

Primary decision question: What happens to closure structures under rainfall and drought outside historical experience?

Accountability: Engineering and risk. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Climate hazard screening and sensitivity cases. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 08: Regulatory data

Primary decision question: Can the regulator reconstruct the estimate, status and instrument for each site?

Accountability: Regulator and information governance. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Digital site register and annual review record. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 09: Progressive release

Primary decision question: What independent performance evidence supports each bond reduction?

Accountability: Regulator and external assurance. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Rehabilitation monitoring and release decision file. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 10: Asset transfer

Primary decision question: Which environmental and maintenance obligations follow transferred roads, power or land?

Accountability: Legal, operations and receiving entity. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Transfer agreement and lifecycle budget. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 11: Investment downside

Primary decision question: What closure funding need arises under low prices, cost inflation and delayed production?

Accountability: Credit committee. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Downside liquidity model and contingency plan. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Decision protocol 12: Relinquishment

Primary decision question: Which residual obligations persist after formal release and who holds the funds?

Accountability: Regulator, trustee and successor. The named group should document whether the issue is an engineering obligation, an accounting estimate, a legal assurance matter, a public-policy exposure or a social-transition commitment. Assigning the correct decision right reduces the risk of a technically important item being treated as a communications issue.

Minimum evidence: Residual-risk register and funded stewardship agreement. Evidence should be current, attributable, independently reviewable and linked to a specific site and reporting date. Where the evidence does not support a firm conclusion, the decision record should state the uncertainty and its consequences for funding, timing or approval.

Escalation: a material discrepancy, near-term safety risk, uncallable guarantee, missing long-tail funding source or unresolved rights obligation should be escalated outside routine reporting. The escalation should identify immediate controls and a date for independent reassessment.

Closeout test: the protocol is complete only when a responsible decision-maker has accepted the evidence, funded any required remedy and specified the next review. A meeting, slide deck or approval signature without supporting documentation does not establish closure readiness.

Decision control	Expected record
Owner	Named role and authority
Evidence	Dated source and independent reviewer
Financial effect	Base and downside funding requirement
Stakeholder effect	Affected rights and interests
Review trigger	Date, event or threshold

Part VIII. Quantitative assurance workbook

Worked example: finite and long-tail obligations

Consider a purely hypothetical mine with direct physical closure works of 100 cost units, indirect and project-management costs of 15, contingency of 25, and an annual real water-treatment obligation of 2 units. Assume a real discount rate of 2% and a 100-year treatment horizon. The treatment annuity factor is [1-(1.02)^(-100)]/0.02, approximately 43.10. The treatment present value is therefore 86.2 units. The combined illustrative requirement is 226.2 units before separate emergency liquidity and model risk.

At a 1% real rate, the same treatment obligation has a present value of approximately 126.8 units. At 4%, the value falls to approximately 49.0 units. Neither rate is a recommended trust return. The exercise demonstrates how assumptions can change the result without any change in the physical mine. A funding policy should explain why a rate is credible and whether it is net of fees, taxes and inflation.

Real rate	Treatment PV	Total illustrative requirement	Ratio to 2% case
1.0%	126.1	266.1	1.18x
1.5%	103.2	243.2	1.08x
2.0%	86.2	226.2	1.00x
2.5%	73.2	213.2	0.94x
3.0%	63.2	203.2	0.90x
4.0%	49.0	189.0	0.84x
5.0%	39.7	179.7	0.79x

The 140-unit initial subtotal comprises 100 direct works, 15 indirect costs and 25 contingency. These are hypothetical inputs. The exercise excludes periodic replacement of treatment assets, extraordinary events and financial-market volatility. A more realistic model would use a year-by-year cash-flow schedule, correlated stress tests and independent engineering estimates.

Worked example: security-accessibility waterfall

Suppose a regulator records 250 units of nominal financial assurance. Of these, 80 are cash, 100 a bank guarantee, 50 a surety bond and 20 a parent undertaking. The face-value total is 250. The accessible amount under an adverse scenario depends on legal claims, issuer solvency, maturity, exclusions and enforcement time. An illustrative haircut of 0%, 10%, 25% and 100% respectively produces 80 + 90 + 37.5 + 0 = 207.5 units of scenario-accessible security.

The haircut percentages are not empirical default probabilities or regulatory rules. They demonstrate why an assurance inventory needs instrument-level risk analysis. The gap between 250 and 207.5 is an illustrative access adjustment, not a claim about any bank, surety or parent entity. A legal opinion and independent credit analysis would replace the hypothetical haircuts in a real review.

Instrument	Face value	Illustrative haircut	Accessible under example
Cash	80	0%	80.0
Bank guarantee	100	10%	90.0
Surety	50	25%	37.5
Parent undertaking	20	100%	0.0
Total	250	n/a	207.5

Worked example: progressive rehabilitation release

A mine may spend 30 units on progressive rehabilitation but reduce the outstanding contractor-executed liability by only 18 units after independent verification. The remaining 12 units of expenditure may reflect initial design, failed work, monitoring or costs that do not eliminate future obligations. The security reduction should follow the independently measured reduction in residual liability, not the amount spent.

A staged release decision might retain a portion of security through a vegetation-establishment period and another portion through long-term water and landform performance tests. The size and timing of retention depend on local law and site risk. This paper proposes a transparent decision record showing work completed, success criteria, evidence period, remaining obligation, released amount and residual risk.

Worked example: a pooled fund under correlated stress

Assume a hypothetical fund holds 500 cost units, expects annual contributions of 60 and normal claims of 20. If three large defaults create 450 units of claims in one year, the fund has limited room for investment losses, emergency operating costs or further defaults. The correct adequacy test therefore considers correlated claims, liquid assets and the legal scope of coverage, not simply whether contributions exceeded claims in a normal year.

A credible pooled-fund model should disclose the portfolio of covered sites, loss distributions, operator risk ratings, eligible costs, contribution formulas, liquidity policy and an independent actuarial review. Public funds also need a priority framework that prevents lower-consequence sites from exhausting resources before severe water or safety hazards are addressed.

Part IX. Factual scrutiny and publication controls

British Columbia funding comparison

C$4.97 billion secured against C$5.40 billion of known major-mine liability is explicitly dated 31 March 2024. The 8% gap is the province's reported characterisation. It is not a current 2026 figure or a global estimate. [R03]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Queensland financial totals

The 2023-24 aggregate estimated rehabilitation cost, surety and fund balance are distinct categories. They are not added or compared without accounting for statutory coverage and timing. [R27]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Western Australia levies

A$51.6 million refers to assessed 2024-25 levies, not the value of total mine rehabilitation liabilities or available fund assets. [R04]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

United States historic assurance

BLM and Forest Service values are explicitly linked to October 2017 and November 2018 respectively. The figures do not describe the current register. [R01]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

UK 2025-26 provisions

GBP1.121 billion mine-water and GBP328 million safety/subsidence provisions refer to 31 March 2026 and carry auditor-noted uncertainty. They are accounting provisions, not a complete global liability estimate. [R20]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

USMIN inventory

An abandoned mine feature is not identical to an abandoned mine site. Counts of features should not be used as counts of distinct mines or sites requiring identical remediation. [R16] [R17]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Chile legal status

Law 20,551 is described as law. SERNAGEOMIN guides are described as administrative guidance for planning and submission. [R07] [R08]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Peru legal status

The official 2025 compendium is cited for law and regulatory amendments, including the March 2025 decree. Site-specific duties still require legal review. [R09]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

EU guarantee scope

The extractive-waste guarantee is not represented as a uniform full-mine security requirement across every member state and activity. [R10]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

South Africa transitional rules

The official 2024 extension is described as a dated administrative status. No unsupported claim is made about every operator’s current deadline. [R30]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

IAS 37 versus security

Accounting provisions are not treated as cash, trust assets or callable bank guarantees. IFRIC 1 is used for changes in decommissioning obligations. [R11] [R12]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

IASB proposals

September 2025 tentative decisions are not described as final enacted amendments. [R13]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Tailings standard

GISTM is described as a global industry standard, not as a universally binding national law. [R14]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Long-tail discounting

The present-value calculations are hypothetical and reproduce the stated equations. They do not claim any mine's actual water-treatment requirement. [R25]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Community participation

The 2025/2026 scholarly article is described as a practice-oriented research contribution, not causal proof of specific employment outcomes. [R24]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Social and labour effects

ILO guidance is used for analytical principles and diagnostic methods, not to assert that all mine closures have identical effects. [R23]

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Currency

Jurisdiction amounts retain original currencies and dates. No cross-country currency conversion is used because the paper does not aggregate unlike balances. Author methodology

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

No global deficit

The paper does not estimate a worldwide mining-closure funding gap because no comparable global site-level denominator and instrument inventory were established. Author methodology

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Original framework

CLOSURE and its 56 indicators are author-developed propositions, not official standards, certifications or empirically validated rankings. Author proposition

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

No unsupported superlatives

Claims of a universal best scheme, largest gap or guaranteed success have been excluded. Editorial control

Scrutiny test: verify the source date, geographic scope, definition, legal status and the distinction between measured facts, forecasts and author interpretation. Where the source does not support a causal claim, report association or an analytical possibility instead. Where a reported value is historical, preserve the period and do not imply it is current.

Part X. Evidence register and source notes

The following entries identify the public sources used for the report. Bracketed identifiers in the text correspond to these entries. Official and academic sources have different evidentiary roles. Readers should consult current laws, permits and financial statements before applying any statement to a particular mine.

[R01] U.S. Government Accountability Office

Hardrock Mining: BLM and Forest Service Hold Billions in Financial Assurances. 2019.

https://www.gao.gov/products/gao-19-436r

[R02] Province of British Columbia

Reclamation securities for mines in B.C.. 22 January 2026.

https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/permitting/mine-reclamation-securities

[R03] Province of British Columbia

Ministry of Mining and Critical Minerals, 2025 Estimates Notes. 27 March 2025.

https://docs.openinfo.gov.bc.ca/Mining_and_Critical_Minerals_Estimates_Notes_2025.pdf

[R04] Government of Western Australia

Mining Rehabilitation Fund Yearly Report 2024-25. 12 December 2025.

https://www.wa.gov.au/government/publications/mining-rehabilitation-fund-yearly-report-2024-25

[R05] Queensland Treasury

Financial provisioning scheme: legislative architecture and 2025 amendments. 2026 access.

https://www.treasury.qld.gov.au/policies-and-programs/resource-sector-financial-assurance/financial-provisioning-scheme/

[R06] Queensland Government

Financial Provisioning Scheme review consultation. 30 September 2026 close.

https://haveyoursay.nrmmrrd.qld.gov.au/financial-provisioning-scheme-review

[R07] Government of Chile

Law No. 20,551 regulating closure of mining operations and installations. 2011.

https://www.doe.cl/viewPublic/document/2011/ley/20551.html

[R08] SERNAGEOMIN, Chile
Mine closure plan presentation and methodology guides. 2026 access.

https://www.sernageomin.cl/guias-de-presentacion-de-planes-de-cierre/

[R09] Ministry of Energy and Mines, Peru
Mine Closure Law and Regulation, 2025 edition. 21 August 2025.

https://www.gob.pe/institucion/minem/informes-publicaciones/4156124-ley-y-reglamento-que-regula-el-cierre-de-minas-ed-2025

[R10] European Commission / Publications Office
Guidelines for mine closure activities and periodic adjustment of financial guarantees. 2021.

https://op.europa.eu/en/publication-detail/-/publication/cdb0af5d-8b8d-11eb-b85c-01aa75ed71a1/language-en

[R11] IFRS Foundation
IAS 37: Provisions, Contingent Liabilities and Contingent Assets. current standard page.

https://www.ifrs.org/issued-standards/list-of-standards/ias-37-provisions-contingent-liabilities-and-contingent-assets/

[R12] IFRS Foundation
IFRIC 1: Changes in Existing Decommissioning, Restoration and Similar Liabilities. current standard page.

https://www.ifrs.org/issued-standards/list-of-standards/ifric-1-changes-in-existing-decommissioning-restoration-and-similar-liabilities/

[R13] IFRS Foundation
IASB Update: Provisions Targeted Improvements, September 2025. 24 September 2025.

https://www.ifrs.org/news-and-events/updates/iasb/2025/iasb-update-september-2025/

[R14] UNEP / ICMM / PRI
Global Industry Standard on Tailings Management. 2020.

https://globaltailingsreview.org/global-industry-standard/

[R15] Intergovernmental Forum on Mining
Mining Policy Framework, updated 2023. 2023.

https://www.igfmining.org/resource/igf-mining-policy-framework/

[R16] U.S. Geological Survey
The Abandoned Mine Inventory of the United States: A Brief Summary. 14 March 2025.

https://pubs.usgs.gov/publication/fs20253003/full

[R17] U.S. Geological Survey
USMIN: Abandoned Mine Lands Inventory. 13 February 2026.

https://www.usgs.gov/centers/gggsc/science/usmin-abandoned-mine-lands-inventory

[R18] U.S. Environmental Protection Agency
Financial Assurance Guidance for Good Samaritan Remediation of Abandoned Hardrock Mines. 5 March 2026.

https://www.epa.gov/cleanups/good-samaritan-remediation-abandoned-hardrock-mines-program

[R19] UK Mining Remediation Authority
Annual Report and Accounts 2025-26, Performance Report. 2026.

https://www.gov.uk/government/publications/mining-remediation-authority-annual-report-and-accounts-2025-to-2026/mining-remediation-authority-annual-report-and-accounts-2025-to-2026-performance-report

[R20] UK Mining Remediation Authority
Annual Report and Accounts 2025-26, Accountability Report. 2026.

https://www.gov.uk/government/publications/mining-remediation-authority-annual-report-and-accounts-2025-to-2026/mining-remediation-authority-annual-report-and-accounts-2025-to-2026-accountability-report

[R21] Queensland Mine Rehabilitation Commissioner
Annual Report 2024-25. 26 September 2025.

https://www.qmrc.qld.gov.au/annual-reports

[R22] IFC / World Bank Group
Environmental, Health and Safety Guidelines for Mining. 2007, accessed 2026.

https://www.ifc.org/en/insights-reports/general-environmental-health-and-safety-guidelines/ehs-guidelines-oil-gas-mining

[R23] International Labour Organization
Green Employment Diagnostics for a Just Transition. 30 June 2025.

https://www.ilo.org/publications/green-employment-diagnostics-just-transition

[R24] Svobodova, Everingham, Mackenzie and Witt
Designing Community Participation for Mine Closure and Social Transition. 2025 online / 2026 issue.

https://doi.org/10.1002/sd.70176

[R25] David M. Chambers
Net Present Value Calculations for Mining Post-Closure Financial Assurance. 26 September 2024.

https://doi.org/10.1007/s10230-024-00995-1

[R26] Intergovernmental Forum on Mining
Relinquishment of Closed Mine Sites: Policy Steps for Governments. 2023.

https://www.igfmining.org/resource/relinquishment-closed-mine-sites-policy-steps/

[R27] Queensland Treasury
Financial Provisioning Scheme Annual Report 2023-24. 2024.

https://s3.treasury.qld.gov.au/files/2023-24-FPS-Annual-Report.pdf

[R28] U.S. Government Accountability Office
Financial Assurances for Reclamation: Federal Regulations and Policies. 2017.

https://www.gao.gov/products/gao-17-207r

[R29] U.S. Government Accountability Office
Hardrock Mining: BLM Needs to Revise Its Systems for Assessing Adequacy. 2011.

https://www.gao.gov/products/gao-12-189r

[R30] South Africa Department of Forestry, Fisheries and Environment
Financial Provisioning Regulations compliance extension. 14 February 2024.

https://www.dffe.gov.za/index.php/mediareleases/financeprovregulations_extensionofcompliancedate

[R31] Queensland Treasury
Financial assurance and rehabilitation in the resources sector. 2026.

https://www.treasury.qld.gov.au/policies-and-programs/resource-sector-financial-assurance/

[R32] Government of Western Australia
Mining Rehabilitation Fund ten-year review. 18 April 2024.

https://www.wa.gov.au/government/announcements/mining-rehabilitation-fund-continues-deliver

[R33] UK Mining Remediation Authority
Data and Information Plan 2024-2027. 2024.

https://www.gov.uk/government/publications/coal-authority-data-and-information-plan-2024-to-2027/coal-authority-data-and-information-plan-2024-to-2027

[R34] Queensland Mine Rehabilitation Commissioner
Annual Report 2024-25, research and practice notes. 2025.

https://www.qmrc.qld.gov.au/__data/assets/pdf_file/0023/408524/qmrc-2024-25-annual-report.pdf

[R35] Global Tailings Review
Global Industry Standard on Tailings Management, full text. 2020.

https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf

[R36] U.S. Government Accountability Office
Mining Operations Oversight. 2026 access.

https://www.gao.gov/mining-operations-oversight

[R37] Gamarra and Orihuela
Resource Booms and Entrenched Gender Roles in the Andes. 2025.

https://doi.org/10.1111/rode.13243

[R38] IFRS Foundation
IASB proposes targeted improvements to provisions. 2024.

https://www.ifrs.org/news-and-events/news/2024/11/iasb-proposes-targeted-improvements-to-requirements-for-provisions/

[R39] Mining Remediation Authority
Annual Report and Accounts 2024-25, Performance Report. 2025.

https://www.gov.uk/government/publications/mining-remediation-authority-annual-report-and-accounts-2024-to-2025/mining-remediation-authority-annual-report-and-accounts-2024-to-2025-performance-report

[R40] Province of British Columbia
Annual reporting for mines in B.C.. 23 April 2026.

https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/permitting/mine-permit-requirements/annual-reporting

Appendix A. 56-indicator scorecard protocol

The scorecard is an evidence-based internal diagnostic. Each indicator receives a maturity score from 0 to 5 only after a reviewer records the evidence, date, responsible institution, materiality and open issues. A blank evidence field means unknown, not zero risk. Fatal flaws are escalated independently of the numerical score.

Cost completeness

Indicator	Objective	Minimum evidence
Physical inventory	Map all disturbed land, structures, wastes, water systems and access routes	Geospatial inventory reconciled to permits and as-built plans

Third-party execution	Price works as if an independent contractor must mobilise after default	Independent rates, mobilisation, demobilisation and supervision
Water and chemical scope	Capture active and passive treatment, reagents, sludge and replacement plant	Chemistry and flow models with annual cost schedule
Contingency	Estimate scope and cost uncertainty by work package	Documented probabilistic or risk-based contingency
Indirect costs	Include management, permits, insurance, taxes where applicable and contractor risk	Work breakdown structure with indirect-cost allocation
Long-tail monitoring	Fund monitoring, reporting and response after construction works	Post-closure operating plan and duration assumptions
Cost escalation	Separate price inflation, sector escalation and quantity growth	Cost index and update policy with real/nominal consistency
Scope reconciliation	Explain differences between engineering, accounting and regulatory numbers	Signed reconciliation by engineering, finance and compliance

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Liquidity and legal enforceability

Indicator	Objective	Minimum evidence
Instrument custody	Establish legal ownership and segregation of assurance assets	Custody confirmation and insolvency legal opinion
Immediate call	Demonstrate timely access to funds after a default event	Tested call procedure and named authorised signatories
Issuer strength	Assess bank, surety, insurer and guarantor credit exposure	Counterparty ratings, limits and concentration dashboard
Maturity coverage	Prevent gaps at expiry or during licence transfer	Renewal calendar and automatic replacement triggers
Currency matching	Manage exchange risk between security and closure costs	Currency sensitivity and hedge or reserve policy
Claim hierarchy	Define order of recourse across cash, surety and trusts	Legal waterfall and no-double-counting reconciliation
Emergency funding	Reserve immediate cash for pumping, treatment and safety	Rapid-access liquidity test and emergency procurement plan
Transfer continuity	Keep security effective through sale, merger or restructuring	Regulator consent and executed replacement instrument

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Operational rehabilitation

Indicator	Objective	Minimum evidence
Progressive works	Complete and verify rehabilitation while productive cash flow exists	Annual disturbed-versus-rehabilitated geospatial reconciliation
Closure design basis	Maintain integrated technical design for final landforms	Approved design basis and independent review
Tailings permanence	Demonstrate geotechnical and hydrological safety post-closure	Instrumentation, consequence analysis and GISTM-related evidence

Water rebound	Model groundwater and surface water after pumping stops	Calibrated hydrogeological model and monitoring triggers
Plant decommissioning	Safely remove hazardous materials and isolate utilities	Hazard survey and contractor method statements
Land-use success	Define measurable final land capability and access	Reference sites, agreed end use and monitoring criteria
Climate resilience	Stress-test structures and vegetation against changing hazards	Flood, drought, wildfire and erosion sensitivity
Emergency response	Maintain contingency capability through suspension and closure	Response plans, funding and drills

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Social transition

Indicator	Objective	Minimum evidence
Affected population	Identify workers, contractors, suppliers and communities at risk	Disaggregated exposure baseline and consultation
Early participation	Begin participatory planning before terminal mine years	Documented engagement process and response record
Employment pathways	Link retraining to real labour-market demand	Placement outcomes and employer agreements
Supplier transition	Reduce single-buyer exposure for local firms	Supplier concentration and diversification indicators
Public services	Plan transfer or continuation of mine-supported services	Municipal budget and service transition agreements
Rights and culture	Respect tenure, heritage and participation rights	Legal review, rights-holder engagement and agreements
Health and safety	Provide risk communication and exposure-based monitoring	Independent testing, referral and grievance mechanisms
Distributional equity	Assess who receives benefits and who bears residual costs	Gender, income and geography impact analysis

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Uncertainty and long-tail risk

Indicator	Objective	Minimum evidence
Scenario completeness	Test more than a single central closure estimate	Defined low, base and severe cases
Treatment duration	Assess finite, extended and perpetual treatment proxies	Hydrochemical evidence and sensitivity model
Discount discipline	Use consistent real/nominal assumptions and conservative returns	Discount-rate disclosure and stress test
Capital replacement	Budget plant, pumps and infrastructure renewal	Asset lifecycle and replacement reserve
Climate shocks	Account for flood, drought, fire and erosion variability	Hazard screening and adaptive trigger levels
Commodity stress	Test simultaneous defaults during low-price cycles	Portfolio stress and correlated default assumptions

Data uncertainty	Record missing, low-confidence and contradictory evidence	Confidence grading and independent verification
Model governance	Version, challenge and periodically recalibrate estimates	Model owner, audit trail and independent review

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Regulatory independence

Indicator	Objective	Minimum evidence
Decision separation	Separate technical approval, custody and security release	Mandate map and segregation of duties
Data systems	Maintain searchable, site-level liability and assurance records	Digital register with geospatial linkages
Update discipline	Review security after disturbance, cost or risk changes	Annual and event-driven update protocol
Independent assurance	Use qualified external technical and financial review	Conflict-of-interest checks and signed opinions
Enforcement capacity	Maintain staff, legal powers and procurement routes	Resourcing plan and tested enforcement procedure
Transparency	Publish comparable information with legitimate redactions	Public summary of liability, security and release status
Cross-agency alignment	Coordinate mining, environment, water and finance roles	Decision-rights map and escalation forum
Institutional continuity	Protect records and duties through personnel or government changes	Records retention and succession protocols

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Evidence-based release

Indicator	Objective	Minimum evidence
Completion evidence	Require as-built records and independent verification	Completion certificates and test results
Performance period	Observe rehabilitation through meaningful seasons and events	Time-series monitoring against thresholds
Residual risk	Identify remaining obligations and finance them explicitly	Residual-risk register and funding instrument
Receiving entity	Confirm successor capacity and legal acceptance	Transfer agreement, budget and asset condition
Rights closure	Resolve agreements, grievances and access duties	Consultation records and dispute-resolution status
Reopening triggers	Define response when new evidence changes risk	Legal and technical reopener conditions
Public disclosure	Explain why security was reduced or released	Published evidence summary and decision rationale
Long-term archive	Preserve models, sampling and design records	Permanent data custodian and open-format archive

Reviewer record: for each indicator document the score, evidence location, date, independent reviewer, corrective action, target date and residual risk. Report the lowest-scoring material indicator

as well as any aggregate score. Do not compare unrelated jurisdictions or mine types using the aggregate alone.

Appendix B. Source-to-claim decision matrix

Official statistical figure

Classification: Observed. Example: 2024 security and liability values. Editorial control: Preserve reporting period, currency, denominator and source.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Audited financial provision

Classification: Observed accounting estimate. Example: UK 2025-26 long-term liabilities. Editorial control: Retain accounting scope and uncertainty note.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Statute or regulation

Classification: Legal fact. Example: Chile Law 20,551. Editorial control: Confirm text, effective date and jurisdiction.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Administrative consultation

Classification: Policy process. Example: Queensland 2026 scheme review. Editorial control: Do not present consultation as enacted change.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Industry standard

Classification: Voluntary or contractual standard. Example: GISTM. Editorial control: Identify applicability and legal status.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Scholarly finding

Classification: Attributed analysis. Example: Long-tail NPV sensitivity. Editorial control: Separate study design from causal claims.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Author framework

Classification: Proposition. Example: CLOSURE scorecard. Editorial control: No claim of official endorsement.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Illustrative model

Classification: Scenario. Example: 2% discount-rate example. Editorial control: Label assumptions and show formula.

A claim should be released only when the reviewer can identify the original source, its measurement period, the precise proposition supported and any relevant caveat. A source citation does not validate a stronger claim than the source itself makes. Comparative assertions require compatible definitions and periods.

Appendix C. Technical glossary

Acid mine drainage: Water affected by oxidation of sulphide minerals, potentially mobilising acidity and metals.

Assurance: A financial or legal mechanism intended to secure fulfilment of closure obligations.

Bank guarantee: A bank undertaking to pay a beneficiary under specified terms.

Care and maintenance: A suspended operational state requiring ongoing safety and environmental controls.

Closure criteria: Defined measurable conditions for accepted mine closure performance.

Contingency: Allowance for uncertainty in cost, scope or events, based on an explicit method.

Cost escalation: Change in costs over time from inflation, market or scope effects.

Decommissioning: Safe removal, isolation or disposal of plant, facilities and systems.

Discount rate: Rate used to translate future cash flows into present values.

Financial provision: Accounting liability recognised under applicable reporting standards.

Financial security: Accessible assets or commitments intended to cover specified obligations.

GISTM: Global Industry Standard on Tailings Management.

Hydrogeology: Study of groundwater occurrence, movement and quality.

IFRIC 1: IFRS interpretation on changes in decommissioning and restoration liabilities.

IAS 37: IFRS standard for provisions, contingent liabilities and contingent assets.

Independent cost estimate: Cost estimate prepared or challenged by qualified professionals separate from the operator's production incentives.

Mine relinquishment: Formal transfer or discharge of defined responsibilities after closure conditions are satisfied.

Net present value: Discounted value of a sequence of future cash flows under stated assumptions.

Post-closure: Period after cessation of closure works when monitoring, maintenance or treatment may continue.

Progressive rehabilitation: Rehabilitation conducted while mine operations continue.

Residual risk: Risk remaining after planned closure controls and works.

Ring-fenced trust: Assets legally segregated for a defined purpose with trustee governance.

Surety bond: Third-party commitment to respond to specified obligations under bond terms.

Tailings: Residual material from mineral processing requiring safe storage and management.

Third-party cost: Cost for an external contractor or authority to perform required works.

Water rebound: Change in groundwater level after mine dewatering stops.

Closing proposition

Mining closure is not a peripheral obligation at the end of extraction. It is a test of whether the economic benefits of a finite activity are matched by durable responsibility for its consequences. The physical work, the accounting estimate, the financial instrument and the social transition must form one coherent system.

The central public-interest question is practical: when a mine stops producing, who pays, who acts, who verifies, and what happens if the original assumptions fail? A system unable to answer those questions before distress begins is not closure-ready, regardless of the nominal size of its provisions.

The standard of responsible extraction should therefore include the credibility of the exit. A mine has not completed its economic story when the final tonne is sold. Its obligations remain until the land, water, people and institutions affected by extraction have a funded and verifiable path beyond production.

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