Mine Closure 2026 – AB Fourie, G Boggs, J Heyes & M Tibbett (eds)

doi:10.36487/ACG_repo/2615_103

Governance for the safe closure of tailings storage facilities: the Engineer of Record perspective

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Abstract

The Global Industry Standard on Tailings Management (GISTM) defines safe closure as the condition in which a tailings storage facility (TSF) presents no ongoing material risks to people or the environment – a condition confirmed by the Independent Tailings Review Board (ITRB) and formally approved by the Accountable Executive (AE). Reaching that state requires satisfying two simultaneous dimensions: a risk dimension, which requires that the facility's failure modes be identified, evaluated and treated under the As Low As Reasonably Practicable (ALARP) principle throughout all life cycle phases; and a governance dimension, which requires that roles and responsibilities be clearly defined so that closure decisions are grounded in engineering analyses with documentary traceability.

This paper examines how the Engineer of Record (EoR) – the role with an explicit mandate for technical continuity across the full TSF life cycle – contributes to the governance dimension of safe closure. The analysis draws on an interpretive review of the GISTM and its Conformance Protocols (ICMM 2021), the ICMM Mine Closure Good Practice Guide (3rd edition) (ICMM 2025b), the ICOLD Bulletin 194 (ICOLD 2025) and the SME Tailings Management Handbook (SME 2022), complemented by the experience of the EoR technical team in closure and post-closure assessments.

The central argument is that safe closure requires the convergence of GISTM tailings governance and ICMM closure governance in the closure plan, and that the technical basis built by the EoR throughout the life cycle – documented in the Design Basis Report (DBR) and its closure-specific version (CDBR), the Construction Record Report (CRR), the Construction versus Design Intent Verification (CDIV), the Deviance Accountability Report (DAR), the Operations, Maintenance and Surveillance (OMS) with its critical controls and Trigger Action Response Plan (TARPs), periodic safety reports and risk assessments – is the condition that enables that convergence to rest on a solid and auditable foundation. Progressive closure and the definition of technically verifiable success criteria are an essential part of that basis: without them, the ITRB cannot confirm safe closure nor the AE formally approve it, and relinquishment remains an aspiration rather than a technically achievable state. The central contribution of the paper is a traceable linkage between the failure modes identified under GISTM Req. 5.4, the design measures documented under Req. 5.6, and the verification criteria recorded in the closure plan – a chain that the EoR must build and maintain across the life cycle as the technical condition for safe closure confirmation.

The paper concludes with practical guidelines for the EoR, the TSF operator, and GISTM conformance assessment bodies.

Keywords: *safe closure, Engineer of Record, GISTM, ALARP, closure governance, tailings governance, TSF life cycle, closure plan*

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1 Introduction

The management of tailings storage facilities presents one of the most demanding technical and governance challenges in the mining industry. A failure – at any stage of the life cycle, including closure and post-closure – can be catastrophic and irreversible, with consequences for people and the environment extending decades beyond the end of operations. In that context, the Global Industry Standard on Tailings Management (GISTM) (GTR 2020) establishes a framework covering the full tailings storage facility (TSF) life cycle, with the explicit objective of achieving zero harm to people and the environment, including zero tolerance for fatalities.

The GISTM applies to all facilities at any life cycle phase. The only formal exclusion applies to TSFs that have reached the safe closure state: once that condition is verified, the standard has fulfilled its purpose for that facility. This design places a concrete governance question at the centre – what must happen, and who must lead it, for a facility to reach that state.

The GISTM identifies two key actors in the confirmation of safe closure: the Independent Tailings Review Board (ITRB), which confirms it technically, and the Accountable Executive (AE), which approves it formally. Alongside them, all roles within tailings and closure governance participate from their specific mandates. Among these, the EoR is the role with an explicit mandate for technical continuity across the full TSF life cycle (GTR 2020, Req. 9.1). A review of the responsibilities assigned by GISTM, its Conformance Protocols (ICMM 2021), the ICMM Mine Closure Good Practice Guide v3 (ICMM 2025b) and the SME Tailings Management Handbook (SME 2022) reveals a specific function: the construction and maintenance of the technical basis that underpins sound closure planning.

The available literature describes the individual roles of the AE, Responsible Tailings Facility Engineer (RTFE), EoR and ITRB in tailings governance (ICMM 2025a; ICOLD 2025; SME 2022), and the structure of closure governance (ICMM 2025b). What this paper develops is the mechanics of how the EoR fulfils its function – through the relationship between the risk assessment (GISTM Req. 5.4), the closure design (Req. 5.6) and the Closure Plan – so that the accumulated technical basis enables the convergence of both governance structures.

The objective is to examine, from the perspective and experience of the EoR technical team, how this role contributes to the governance of safe closure throughout the TSF life cycle. The analysis covers the sequence Req. 5.4 → Req. 5.6 → closure plan, the concept of the Closure Design Basis Report (DBR) as an instrument for consolidating the technical basis, progressive closure as an anticipatory application of the closure design, and closure success criteria as a condition for relinquishment. The analysis integrates observations from practice in independent technical reviews that recurrently highlight the need to involve the EoR in the feasibility design of the closure plan, as a condition for that planning to be grounded in the actual, accumulated technical basis of the facility.

2 Methodology

This paper draws on three complementary analytical components.

The first is a review of normative and good practice frameworks selected for their direct relevance to TSF closure governance. The documents reviewed include the GISTM (GTR 2020) and its Conformance Protocols (ICMM 2021), the Tailings Management Good Practice Guide second edition (ICMM 2025a), the Integrated Mine Closure Good Practice Guide third edition (ICMM 2025b), the ICOLD Bulletin 194 (ICOLD 2025) and the SME Tailings Management Handbook (SME 2022). It should be noted that the ICMM Conformance Protocols (2021) are not equivalent to the GISTM but rather the operational instrument that translates its requirements into auditable criteria and minimum design criteria by life cycle phase; the ICOLD Bulletin 194 (2025) provides a dam safety perspective that is complementary to, but not identical with, the GISTM's governance approach. The selection prioritised documents that explicitly define EoR roles, responsibilities and sets of technical documents, as well as requirements for the declaration of safe closure.

The second component is an interpretive analysis of the GISTM governance roles – AE, RTFE, EoR and ITRB – with emphasis on how their mandates contribute to the safe closure objective. The analysis examines the responsibilities that the standards assign to the EoR in risk assessment, closure design and the closure plan, with the aim of identifying the logic connecting those elements in closure governance.

The third component is the integration of practical experience from the EoR technical team in closure and post-closure assessments of tailings facilities, aimed at identifying recurring patterns where technical continuity proves decisive. This experience draws from independent technical reviews of TSFs at multiple life cycle stages – including facilities in active operation, late-stage closure planning, and post-closure monitoring – across different tailings deposition technologies and geotechnical settings. The conclusions represent the authors' technical judgement, grounded in the reviewed standards. The value of this approach lies in its transferable scope: the patterns identified and the traceability chain proposed are applicable to facilities at different life cycle stages and operational contexts, regardless of scale or deposition technology.

3 Safe closure and its 2 dimensions

The GISTM defines safe closure as the condition in which a TSF presents no ongoing material risks to people or the environment, confirmed by the ITRB and approved by the AE (GTR 2020). In this context, ongoing material risks are those that, if left uncontrolled, could lead to serious and sustained consequences for human life or the environment. The magnitude of that time horizon is not trivial: ANCOLD (2023) and ICOLD (2025) establish that physical and geochemical stability assessments for facilities in permanent passive closure must consider time horizons of 200 to 1,000 years or more, reflecting the period during which the facility will be exposed without active management. This condition represents the technically stable and long-term sustainable state that the standard seeks to achieve.

Reaching that condition requires satisfying two dimensions: a risk dimension and a governance dimension. The risk dimension requires that the potential failure modes of the facility be identified, evaluated and addressed to minimise risk according to the As Low As Reasonably Practicable (ALARP) principle, and that these outcomes be considered in the design (GTR 2020, Req. 5.4), including the closure design (Req. 5.6). To demonstrate that a facility presents no ongoing material risks, assessments must consider geotechnical, geochemical and hydrological stability in closure condition – among other site-relevant dimensions – with the analytical rigour appropriate to that life cycle phase.

A technical aspect with direct consequences for the EoR's documentary basis is the required progression in assessment level. The ICMM Conformance Protocols (2021) are compatible with conceptual assessments at early life cycle stages. However, demonstrating safe closure requires semi-quantitative or quantitative assessments to validate the condition of presenting no ongoing material risks (ANCOLD 2023). The EoR must plan that progression from early operational stages, ensuring that stability reports and associated risk assessments reach the required level of detail before the closure phase begins. Reaching closure with only qualitative assessments – without having advanced to the semi-quantitative or quantitative level that the closure condition requires – leaves the ITRB without the technical basis needed to confirm safe closure.

The governance dimension requires that technical roles and responsibilities be clearly defined and coordinated so that closure planning decisions are grounded in engineering analyses with documentary traceability. In this structure, accountability rests with the AE and cannot be delegated – what the AE delegates are execution responsibilities and the authority for Closure Plan development and TSF life cycle management (GTR 2020; ICMM 2025a). The ICMM Mine Closure GPG v3 is explicit that regular engagement between tailings governance roles – particularly the EoR – and the Closure Champion is critical to ensuring that closure considerations are integrated throughout the asset life (ICMM 2025b).

Although tailings governance and closure governance may differ in structure at the corporate or site level (ICMM 2025a), both converge in the closure plan as the planning instrument. The EoR participates in that convergence from its specific function: it preserves design intent, documents facility performance and identifies risks throughout the life cycle, providing the technical basis that enables the ITRB to confirm and the AE to approve safe closure.

GISTM Req. 5.5 requires that designs be developed for each construction stage of the facility, including all closure stages (GTR 2020) distinct from Req. 5.6, which governs the design of the closure phase itself. The Conformance Protocols specify that closure designs must reach at least prefeasibility level as a conformance condition (ICMM 2021, Req. 5.5). This requirement has a direct consequence for the EoR's documentary basis: the DBR must record not only the operational design criteria but the progressive evolution of closure criteria at each phase. As the TSF approaches closure, the SME recommends that the EoR develop a closure-specific Design Basis Report – a Closure DBR (CDBR) – which starts from the operational DBR and expands in detail on the closure design and post-closure plans, incorporating the facility's long-term material properties and loading criteria specific to the passive closure phase (SME 2022). The CDBR is the instrument that consolidates the accumulated technical basis and translates it into closure-specific criteria that are auditable by the ITRB.

Figure 1 illustrates how both governance structures converge in the closure plan.

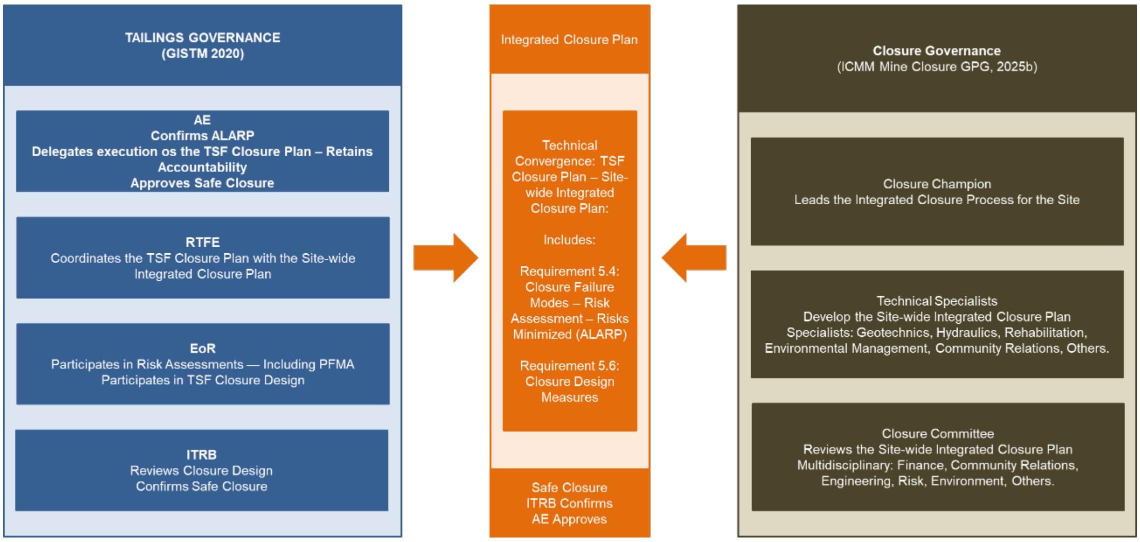

Figure 1 Convergence of tailings governance (GISTM) and closure governance (ICMM) in the closure plan

4 The EoR across the life cycle: technical basis for safe closure

GISTM Req. 9.1 establishes that the EoR performs its function across the full life cycle of the facility – from conception through closure and post-closure (GTR 2020). This continuity mandates position the EoR as the actor that preserves design intent, documents observed performance and progressively identifies risks, building the technical basis that safe closure requires.

The central document of that basis is the Design Basis Report (DBR). GISTM Req. 4.8 establishes that the EoR must prepare the DBR, a record of design assumptions and criteria – including performance conditions and criteria for each life cycle phase – that provides the basis for the design of the facility (GTR 2020). The EoR initiates the DBR at the conceptual design stage and incorporates into it, from that point, the loading criteria specific to passive closure. Whenever there is a material change to design assumptions, criteria, geotechnical or geochemical characterisation, or site and deposit conditions, the EoR updates the DBR and confirms the internal consistency of its elements (SME 2022).

The EoR's responsibilities most relevant to closure governance are organised into five functions.

The first is the management of the technical knowledge base. The EoR keeps the DBR up to date with performance data, geotechnical and geochemical investigations, and material changes to the design. Dam Safety Inspections (DSIs) are the periodic instances at which the EoR evaluates the facility's overall performance against the DBR criteria, identifying deviations with implications for the closure condition. Stability and seepage analyses are updated at key life cycle milestones, or following geometry changes, major climatic events, or changes in loading conditions relevant to closure.

The second function is documentation of the as-built condition and verification of design intent. The EoR prepares or reviews the Construction Records Report (CRR), which documents the as-built state of the facility. The Construction Design Intent Verification (CDIV) process confirms that conditions encountered are consistent with the DBR assumptions. Unresolved deviations are recorded in the Deviance Accountability Report (DAR), which evaluates their cumulative impact on the risk level of the constructed facility (GTR 2020, Req. 6.5). The DAR is approved by the AE, making change management a process with accountability at the highest level of governance.

The third function is participation in periodic risk assessments. The EoR contributes to Potential Failure Modes Analyses (PFMAs) and periodic risk assessments as part of the multidisciplinary team, identifying credible failure modes and informing the risk management plan with their critical controls and associated surveillance (ICMM 2025a; ICMM 2025b).

The fourth function is the preparation and maintenance of the OMS manual. The EoR prepares the OMS manual in coordination with the RTFE and operations team: it is the document governing activities under normal operating conditions, defining maintenance and surveillance procedures, establishing the expected performance criteria for each critical control identified in risk assessments, and setting the thresholds above which those criteria are considered exceeded (SME 2022; ICMM 2025a). TARPs articulate with the OMS by defining response actions when those criteria are exceeded; the Emergency Preparedness and Response Plan (EPRP) activates when conditions surpass the TARP's scope. OMS, TARPs and EPRP are distinct but articulated documents, with the TARP acting as the transition mechanism between the other two. The EoR must ensure that all three documents are aligned and updated whenever there are material changes to the design or facility condition.

As closure approaches, the operational OMS must give way to a closure OMS that the EoR must update or develop. This document no longer governs an active operation: its purpose is the long-term maintenance and surveillance of a facility that has no active water management, receives no further tailings deposition and is exposed to different loading conditions. The critical controls of the closure OMS respond to the failure modes specific to that condition; TARPs must be recalibrated to the thresholds corresponding to long-term parameters; and the EPRP must be aligned with the failure scenarios of passive closure. The update of this OMS–TARP–EPRP triad for the closure condition is part of the closure engineering that the EoR supervises, and its traceability to the CDBR provides its technical foundation.

The fifth function is technical analysis in support of the closure plan. EoR provides the engineering analyses underpinning the development of the TSF Closure Plan and holds a technical review and approval role over that plan regardless of who authors it – when external closure specialists are involved, the EoR must provide oversight, input and approval (ICMM 2025b, Table 2). The level of detail of that analysis must be proportional to the life cycle stage: the ICMM Conformance Protocols specify that the closure design must reach at least pre-feasibility level, and the Integrated Mine Closure Guide establishes that the Closure Plan must progress from conceptual to detailed level as closure approaches (ICMM 2021; ICMM 2025b).

A specific risk to life cycle governance is the change of EoR. The ICMM GPG (2025a) is explicit that the selection, retention and eventual change of EoR must never be based solely on cost considerations, and that the loss of technical continuity in that transition is one of the most underestimated governance risks. For safe closure, that continuity is critical: an EoR change without a documented, transferable and audited technical basis forces the incoming EoR to reconstruct the facility's technical history from fragmented records, with the risk that the failure modes relevant to closure are not adequately identified when planning the Req. 5.6 design measures.

Table 1 shows the documents the EoR builds throughout the life cycle and how each document contributes to the technical basis that the closure plan requires.

Table 1 EoR responsibilities by TSF life cycle phase and associated technical documents

Life cycle phase	EoR function	Associated documents
Conception and design	Establishes design assumptions and criteria for all life cycle phases, including closure. Defines passive closure loading criteria from the outset.	DBR (initial version)
Construction	Documents the as-built condition; verifies conformance with design intent; evaluates the cumulative impact of deviations on the risk level of the constructed facility.	CRR – CDIV – DAR
Operation	Periodic performance assessment; identifies credible failure modes including those relevant to closure; updates the technical basis upon material changes; manages change management with focus on closure feasibility.	DBR (updated) – DSI – PFMA/RA – DAR
Closure	Reviews closure engineering against the Closure DBR; ensures design measures address identified failure modes and are consistent with Req. 5.6; updates OMS for transition to long-term maintenance and surveillance; recalibrates TARPs and aligns EPRP with passive closure failure scenarios.	Closure DBR – OMS (closure version) – Recalibrated TARPs – Updated EPRP
Post-closure	Monitors residual risks in accordance with the closure OMS and TARPs; updates the technical basis in response to unforeseen behaviour; confirms that closure performance criteria are maintained over the long-term as a condition for relinquishment.	Closure OMS – TARPs – EPRP – Updated Closure DBR

5 The technical chain: from risk (Req. 5.4) to closure design (Req. 5.6)

The EoR is not the author of the closure plan – that role belongs to the professionals of closure governance. EoR’s role is to actively participate in closure plan development, review its technical content and ensure that the information contributed by tailings governance is correctly incorporated. In practical terms, this means the EoR must verify that the closure plan contains the traceability between the facility's failure modes, the closure design measures and the verification criteria, and identify the technical studies needed to resolve uncertainties not yet sufficiently supported by the facility's knowledge base.

GISTM Req. 5.4 requires that all potential failure modes be addressed to minimise risk to ALARP, and that those assessments inform the design. Req. 5.6 requires that the closure design demonstrates the feasibility of the closure scenario in sufficient detail. The relationship between the two is direct: each closure design measure is a risk treatment originating in an identified failure mode. EoR must ensure that this correspondence is traceable in the closure plan – so that any reviewer can verify which risk each measure addresses and with what performance criterion.

This logic is articulated in three steps.

Figure 2 illustrates this technical chain, from the EoR technical basis through the risk management process required by Req. 5.4, to the closure design under Req. 5.6, and the documentation of traceability in the Closure Plan as the condition for ITRB confirmation and AE approval of safe closure.

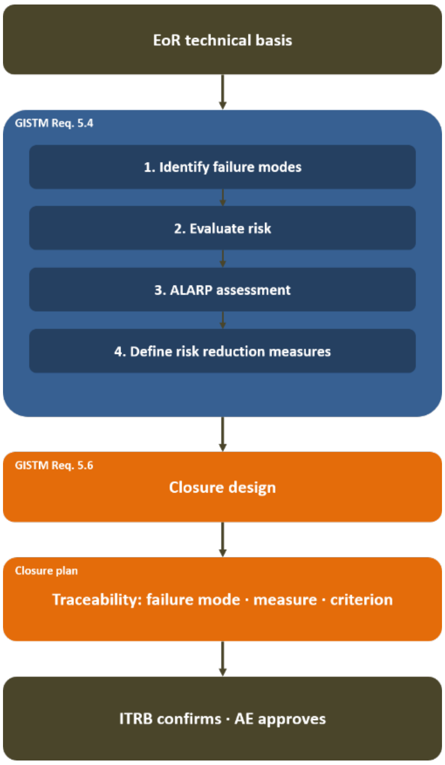

Figure 2 The technical chain: from risk assessment (Req. 5.4) to closure design (Req. 5.6) and traceability in the Closure Plan

5.1 Identification of risks in closure condition

The first step is to identify which risks must be addressed in closure conditions. Failure modes relevant during operation may behave differently once operations cease – in some cases, more severely. There are three technical reasons for this. First: loading conditions change, because the GISTM requires extreme consequence seismic and hydrological criteria for passive closure that are more demanding than operational ones. Second: active controls disappear, because pumping, water treatment and controlled tailings deposition cease to exist as control mechanisms. Third: material properties evolve over the long-term, because tailings consolidation, phreatic surface variation and geochemical behaviour in the absence of active management may differ substantially from the operational parameters recorded in the DBR. Each of these reasons generates failure modes that the Closure Plan must address explicitly.

A clearly documented example is seismic stability. During operation, the seismic design criterion responds to the facility's consequence classification at that phase. In passive closure conditions, the GISTM requires adopting extreme consequence criteria – Annual Exceedance Probability (AEP) 1:10,000 events or maximum credible earthquake regardless of the operational classification (GTR 2020). What this means in practice is that the EoR must update stability analyses with the long-term properties of the tailings – advanced consolidation, post-closure phreatic surface – and verify that the embankment slopes satisfy the factors of safety required for that loading condition. In facilities where this update has not been carried out, the facility may reach closure with a seismic risk that the Closure Plan has not explicitly evaluated under the criteria required by the standard (SME 2022; ANCOLD 2023).

A second example is the generation of acid drainage in post-closure conditions. During operation, the active water management system – pumping, treatment, recirculation – controls the mobilisation of contaminants. When operations cease, that control disappears: the deposit is exposed to precipitation and phreatic fluctuations without active intervention. If the material has acid-generating potential, the closure failure mode is the uncontrolled release of leachate, with consequences that may extend over decades. This is precisely the type of failure mode that only the EoR can identify from the specific knowledge of the deposit

– its geochemical characterisation, the history of the water management operation and the post-closure site conditions – and which must be documented with its treatment measures and verification criteria in Req. 5.6.

5.2 Definition of treatment measures with verifiable criteria

The second step is to define the treatment measures that address each identified closure risk. Each failure mode must have a design measure under Req. 5.6 with specific and verifiable criteria – minimum factors of safety, return periods, geochemical thresholds or long-term geomorphic stability criteria, as applicable. The level of specificity required increases as closure approaches: from a feasibility assessment at early stages to a detailed, executable design at the point of closure.

It is common for the Closure Plan to operate at conceptual level during early operational stages – which is consistent with the ICMM Conformance Protocols (2021). What is not consistent with the standard is for that conceptual level to remain unchanged as the life cycle advances and the facility's technical basis is enriched with actual performance data. Each DBR update during operation is an opportunity to refine the closure design criteria, and the EoR must ensure that update occurs and is recorded.

5.3 Documenting traceability in the Closure Plan

The third step is to document in the closure plan the traceability between failure mode, treatment measure and verification criterion. For each identified closure risk, the closure plan must be able to answer three questions: which measure addresses it? What performance criterion must be achieved? And how will it be verified that the criterion has been met? These are the questions the ITRB must be able to answer affirmatively to confirm safe closure, and the EoR is responsible for ensuring the closure plan’s technical basis provides those answers.

TSF’s design intent is unique and spans the full life cycle. Operational and closure conditions are phases of the same design – what varies between phases are the loading conditions, performance criteria and available controls. The DBR must record that evolution, and the closure criteria must be consistent with the closure plan objectives at each update.

One dimension of the technical chain that warrants further precision: Req. 5.6 of the GISTM is not limited to requiring a closure design at the end of the life cycle. It explicitly establishes that the design must “allow implementation of elements of the design during construction and operation as appropriate”, and that it should include progressive closure and reclamation during operations (GTR 2020, Req. 5.6). This provision has a concrete technical implication for the EoR: progressive closure is not merely good environmental rehabilitation practice – it is the anticipatory application of Req. 5.6 throughout the life cycle. Each work element executed during operation that forms part of the closure design – outer slope geometry built to the final closure angle from the outset, installation of a perimeter drainage system sized for closure condition, progressive revegetation of completed areas – reduces the technical and economic gap between the operational and passive closure condition (SME 2022). The EoR must verify that those works are consistent with the closure design documented in the DBR or CDBR, or that deviations are recorded in the DAR with an assessment of their impact on the safety of the facility and the feasibility of closure, leaving an auditable record. This function of verifying progressive closure is part of the EoR's ordinary mandate, not a task that begins as closure approaches.

6 Governance convergence in the Closure Plan

The ICMM Mine Closure GPG v3 establishes that the closure of a TSF involves actors from two distinct governance structures. Tailings governance – AE, RTFE, EoR and ITRB – operates under the GISTM with a focus on the technical safety of the facility across its life cycle. Closure governance – Closure Champion, technical specialists and Closure Committee – operates with a focus on the integrated closure objectives of the operation. While both structures share the safe closure objective, they may differ in composition and management instruments at the corporate or site level (ICMM 2025a). The closure plan is the instrument where they converge.

The ICMM (2025b) is explicit that regular engagement between tailings governance roles – particularly the EoR – and the Closure Champion, is critical for ensuring the integration of closure considerations throughout the asset life. The quality of that convergence depends on each role contributing from its mandate. The EoR's contribution materialises in three planes.

The first is the transfer of technical knowledge to the Closure Committee. The EoR makes available to the Committee and its specialists the facility-specific knowledge – geotechnical and geochemical characterisation, construction history, observed performance and credible failure modes – documented in the DBR, CRR, OMS, DSI reports and DAR. This interaction is not unidirectional: the Committee's technical specialists provide the EoR with disciplinary criteria on rehabilitation, water and environmental matters that inform the feasibility assessment of closure strategies.

The second is the construction of the closure plan as a technically grounded instrument. The EoR ensures that the closure plan is backed by the traceability documented in the DBR, CRR, CDIV and DAR. This documentary base converts the closure plan into an auditable instrument: any closure governance decision can be traced back to the technical analyses that underpin it, which is particularly relevant in the event of changes in operator or EoR.

The third is the ongoing assessment of the impact on closure feasibility. During the operational phase, the EoR evaluates whether material changes have implications for closure feasibility, documenting them in the DAR and keeping them visible for the Closure Committee and the RTFE (ICMM 2025a). This function prevents the TSF from reaching closure with residual risks not considered in planning.

The authors' experience in the EoR role – accumulated across twelve tailings storage facilities with different deposition technologies (conventional and thickened), different embankment construction materials (cycloned sand and rockfill), and different life cycle stages (active operation, approaching closure, and inactive) – allows the identification of three recurring situations where the lack of continuity in the technical basis generates concrete gaps.

The first involves facilities where the verification of seismic stability under passive closure criteria had not been updated with the long-term properties of the tailings. This situation has been identified by the authors in independent technical reviews of TSFs at different life cycle stages. The problem is not only numerical: the difference between operational and long-term parameters can be substantial in deposits with high plasticity or low consolidation, and both ANCOLD (2023) and SME (2022) explicitly require that verification to be carried out with the deposit's long-term material parameters. The closure plan assumed operational loading criteria that the GISTM does not permit for the passive closure condition, and the available stability reports did not cover that loading condition with the required parameters.

The second situation involves deposits with material design changes not documented in the DAR. The ICMM GPG (2025a) is explicit that the change management process must evaluate the impact of each change on closure feasibility – not only on the current operation. A geometry change that does not compromise operational stability may alter the loading criteria for the passive closure phase defined in the DBR or change the long-term phreatic surface distribution. When this analysis is not carried out and documented in the DAR, traceability at the point of closure breaks down and the EoR must reconstruct the history from fragmented records.

The third situation involves closure plans that do not incorporate the credible failure modes identified in the EoR's periodic risk assessments. These plans have advanced in parallel to the facility's technical management without explicit integration: they contain rehabilitation, cover and revegetation strategies, but do not establish the correspondence between each measure and the failure mode it addresses. The difference between an auditable closure plan and one that is not reduced precisely to that traceability. When the ITRB reviews the plan to confirm safe closure, the absence of that correspondence prevents it from answering affirmatively the questions the standard requires.

The ICOLD Bulletin 194 (ICOLD 2025) states that at each design stage – from conceptual through detailed – the feasibility of safe closure must be confirmed. The integration of closure analysis into the EoR's technical basis is therefore a continuous process that consolidates in the closure plan when the facility initiates its transition to closure.

One element connecting the EoR's technical basis to the formal confirmation of safe closure is the concept of closure success criteria. The ICMM Mine Closure GPG v3 defines success criteria as the measurable and verifiable thresholds that allow confirmation that closure objectives have been achieved – and that form the basis on which the ITRB can pronounce on the safe closure status (ICMM 2025b). Success criteria are not exclusively environmental or social in nature: they include technical dimensions directly derived from Req. 5.6. The minimum factors of safety under passive closure loading conditions, geochemical thresholds for leachate neutralisation, hydrological return periods that the drainage system must accommodate – all are closure success criteria from the tailings governance perspective. The EoR is the actor that must define those criteria with technical precision and document them in the CDBR and the closure plan, so that the other governance actors can verify their fulfilment.

The articulation between success criteria and the EoR's technical basis has consequences that extend to post-closure. Relinquishment – the transfer of responsibility for the TSF to the next land user – requires demonstrating that the agreed closure criteria have been satisfied (SME 2022). That demonstration depends on the criteria being documented with sufficient precision to be verified during the post-closure period. An closure plan that defines closure objectives without technically verifiable criteria indefinitely defers relinquishment, with the attendant financial and regulatory consequences. The technical basis built by the EoR – the Req. 5.6 design criteria documented in the CDBR, the traceability to the Req. 5.4 failure modes, the monitoring plans that verify fulfilment of those criteria over the long-term – is the condition that makes relinquishment not a planning aspiration but a technically achievable state.

Post-mining land use is a dynamic input to closure planning, defined by the closure governance process through stakeholder engagement and subject to evolution throughout asset life. When the post-mining land use is defined or updated, the EoR incorporates it into the design intent documented in the Closure DBR and verifies that the closure measures are compatible with that use. The agreed land use thus translates into technically verifiable criteria – geomorphic stability thresholds, revegetation performance standards, water quality objectives – that the EoR documents in the closure plan and against which closure performance can be confirmed.

7 Conclusion

The safe closure of a TSF is not a condition reached at the end of the life cycle: it is the result of technical decisions made – or omitted – from project conception. The technical basis the EoR builds throughout the life cycle, documented in the DBR, the CRR, CDIV and DAR, safety reports and periodic risk assessments, is the condition that enables the ITRB to confirm and the AE to approve that state on solid and auditable foundations.

The argument developed in this paper rests on a verifiable technical logic: the credible closure failure modes must be identified and treated under ALARP (GISTM Req. 5.4); the corresponding design measures must be documented with verifiable criteria in Req. 5.6; and the traceability between the two must be recorded in the closure plan as an auditable instrument of closure governance. The EoR is the role with the mandate and technical continuity to ensure that chain is built across the life cycle – not in response to closure requirements as they approach, but as part of ordinary engineering practice.

For the EoR and its team, the contribution to safe closure begins at project conception: passive closure loading criteria must be incorporated in the initial DBR and updated at each revision as performance data accumulate. Closure failure mode analysis must form part of each PFMA update during operation. Progressive closure – the construction of closure design elements during operation – must be verified against the DBR or the CDBR at each DSI. As the TSF approaches closure, the EoR must develop the CDBR and actively participate in defining the closure success criteria: the technically verifiable thresholds that allow the ITRB to confirm safe closure and open the path to relinquishment.

For the operator, formal coordination between the tailings engineering function and closure planning is the condition that enables both governance structures to operate on the same technical basis. Establishing mechanisms that include the EoR in the Closure Committee from the feasibility stages, and that the DBR explicitly records closure considerations at each update, reduces the risk of the TSF reaching closure with unanticipated technical gaps. EoR continuity across the life cycle must be managed as a governance risk: EoR transition processes must ensure that the documented technical basis is transferable and auditable.

For GISTM conformance assessment bodies, audit frameworks gain depth by verifying the traceability between the Req. 5.4 failure modes and the Req. 5.6 measures in the closure plan. Verifying that the closure plan effectively addresses the credible failure modes identified in periodic risk assessments, with verifiable criteria and at an assessment level consistent with the life cycle phase, provides a concrete and auditable basis for the confirmation of safe closure.

The empirical validation of the proposed traceability chain in TSF closure plan's at different life cycle stages, and the development of assessment protocols to verify the level of closure integration achieved, represent the highest-value lines of future work in the field.

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