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Re-imagining tailings: a vision for safe, sustainable mining

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Abstract

Managing tailings is one of the mining industry's most significant challenges and one of its greatest opportunities. Decisions made today about how we manage and re-imagine tailings will play a major role in determining what the future direction of mining looks like, including the level of trust placed in the sector by communities and regulators.

In recent years, we have seen real progress: stronger global standards, better monitoring tools, and new technologies that help reduce risk and improve the way we design and operate facilities. These steps are helping us move toward a future where catastrophic failures can be prevented and where communities, investors, and regulators can have greater confidence in how we operate. Through innovation, the mining industry can not only improve the way it manages existing facilities but reshape how companies understand and manage risk and deliver value alongside improved safety and sustainability outcomes.

This paper will look at where we stand today, sharing examples of innovation and collaboration already happening across the industry. It will also explore where we can go from here, outlining a vision of what the future could hold: a future where tailings facilities are inherently safer by design, where water and waste are managed more efficiently, and where the industry's approach to tailings can become a model of environmental stewardship. Through collaboration with technology innovators, suppliers and academia, it is possible to drive collective action and overcome persistent challenges in piloting and scaling new approaches.

Keywords: *collaboration, standards, stewardship, tailings innovation*

1 Introduction

Tailings are one of the most enduring legacies of mining. Long after a mine closes, tailings facilities remain shaping landscapes, influencing ecosystems, and informing public and regulatory perceptions of how responsibly the mining industry operates. As a result, tailings management has become one of the most visible measures of mining performance, with expectations rising sharply. Communities rightly demand safety and transparency, while investors continue to scrutinise tailings risk as a material governance issue. At the same time, regulators expect stronger assurance and accountability. The mining industry must demonstrate that it can supply the materials needed for development and the energy transition without harming people or the environment.

Since 1915, more than 250 global tailings facility failures have been recorded, resulting in fatalities, environmental damage and long-lasting social harm for affected families and communities. More than half of total recorded released volumes have occurred since 2000, leading to the loss of hundreds of lives and the release of millions of tonnes of material to the surrounding environments (Piciullo et al. 2022). These events underscore a critical lesson: that tailings management can no longer be viewed as a purely technical or peripheral issue, but must be recognised as a challenge of leadership, governance and broader systems thinking.

The scale of the challenge is growing faster than ever. Globally, an estimated 13 billion tonnes of tailings are generated each year, contributing to an existing inventory of approximately 282 billion tonnes stored in

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tailings facilities worldwide (Hudson-Edwards et al. 2024). At the same time, demand for minerals and metals continues to rise, driven by population growth, economic development and the global transition to low-carbon energy systems. It is estimated that around 300 new mines will be needed by 2040 to produce the 3 billion tonnes of metal needed to supply the energy transition alone (Benchmark Source 2022). To further complicate this, demand for minerals is increasing as average ore grades decline and orebodies become more complex (International Council on Mining and Metals [ICMM] 2025). As a result, more material must be mined and processed to produce the same amount of metal, increasing both the volume and longevity of tailings generated under conventional mining approaches.

As tailings volumes are expected to rise significantly, their management will be central to the industry's ability to protect the environment, build trust and create long-term value. Indeed, tailings present significant opportunities for value creation with an estimated USD 16.9 billion current market value. This is forecast to reach USD 24 billion by 2023 (Data Bridge Market Research n.d.), with upwards of USD 2.5 trillion estimated value in metals and minerals contained in accumulated tailings (Mining Visuals 2025).

The way tailings are generated, managed and governed today will define the future of mining tomorrow. Compliance with standards, while essential, is no longer sufficient on its own. Growing expectations from communities, investors and regulators are increasingly focused not only on preventing failure, but on whether mining companies are demonstrating foresight and responsibility in how they manage waste across the full mining life cycle.

By reframing tailings not only as a risk to be managed, but as a strategic challenge and opportunity, the industry can move beyond incremental improvement toward fundamentally safer and more sustainable outcomes. Re-imagining tailings offers a pathway to reduce long-term liabilities, strengthen trust with communities and society, and ensure that mining can continue to supply the materials the world needs with integrity and confidence. This is an ambitious challenge that requires an integrated approach across most parts of the mining process, with support from policy, regulation, and the brightest minds working on solutions.

2 Where we stand today: progress, momentum and what we've learned

Over the past decade, catastrophic incidents – Mount Polley (2014), Samarco (2015), and Brumadinho (2019) – prompted the industry to address longstanding weaknesses in governance and transparency. In response, in 2020 ICMM, the United Nations Environment Programme, and the Principles for Responsible Investment initiated the Global Tailings Review which resulted in the establishment of the *Global Industry Standard on Tailings Management* (GISTM). With 15 principles and 77 requirements, GISTM was developed to prevent catastrophic failures of tailings facilities. It integrates social, environmental, local economic, and technical considerations, with the goal of zero harm to people and the environment and zero tolerance for human fatality.

Implementation of GISTM has transformed company practices, establishing board-level oversight, independent review, and enhanced technical roles. Investment in engineering, data quality, monitoring, and engagement has elevated tailings management to a strategic priority. By August 2025, 67% of ICMM members' applicable facilities were fully conformant with GISTM, with ongoing efforts to expand adoption and capacity-building.

However, conformance is not the end point. Tailings facilities are dynamic, requiring regular review and adaptation as conditions change. Regional disparities in regulation and resources affect progress, and good tailings management is now a baseline expectation. The next leap forward will come through innovation. Successful outcomes will be built not only on unwavering long-term commitment by companies, but also close collaboration between the industry, its financers, governments, civil society and communities local to sites.

ICMM members are advancing technologies to reduce, re-use, and re-imagine tailings, including alternative recovery, precision processing, dewatering, and valorisation approaches. This represents a shift from risk management to systemic redesign.

3 Innovation is changing the risk landscape

Companies have long focused on keeping tailings facilities safe and well-managed, but the industry is now moving beyond traditional practices. As understanding has evolved, mining companies are increasingly exploring new and innovative ways to manage tailings more effectively, adopting more integrated and sophisticated practices that respond to the geological, hydrological and social realities of individual operations. As these practices have evolved, so too has the understanding of what meaningful progress requires. Innovation in tailings is not only about new technologies or improved tools; it is a process, an outcome and a mindset (Kahn 2018). It requires clarity about the outcomes being pursued, deliberate organisation of the work needed to bring new approaches to fruition, and the supportive cultures, governance systems and external conditions — regulatory, financial and policy-related — that enable new ideas to take hold.

This section highlights practical examples that illustrate how innovation is contributing to a changing risk landscape in tailings management and supporting continuous improvement. It sets the foundation for the more detailed exploration of reduce, re-use and re-imagine pathways in greater depth in Section 4.

3.1 How practical innovations are improving risk today

Across ICMM members, a diverse set of site-specific innovations is expanding what responsible tailings management can achieve. Although each initiative responds to specific site conditions, we identified common themes across 4 areas of progress: strengthening stability, supporting long-term stewardship, building trust with communities and local authorities, and improving decision quality.

Table 1 summarises how the case studies included in this section map onto these 4 dimensions.

Table 1 Case studies organised by key areas of risk improvement

Area	Company/site (commodity)	Innovation/approach	Contribution to risk management
Strengthening stability	Anglo American (portfolio-wide)	Waterless mine; coarse particle recovery, hydraulic dewatered stacking, novel leaching processes	Reduced reliance on wet deposition, improved long-term stability
	Hydro – Paragominas (bauxite)	Dry backfill (>60% solids), placement in mined-out area	Drier, more stable landforms; safer long-term performance
Supporting long-term stewardship	Freeport-McMoRan – Sierrita (copper)	Commingling trials (6 pads, 25+ blends)	Potential for enhanced stability through mixed materials
	Hydro – Paragominas (bauxite)	Dry backfill and progressive rehabilitation	Reduced need for new tailings storage facilities; smaller long-term footprint
Building transparency and trust	Minera Centinela (copper)	Public, municipality-led flood simulation (400+ people)	Strengthened emergency readiness and community confidence

Area	Company/site (commodity)	Innovation/approach	Contribution to risk management
	Rio Tinto (portfolio-wide)	Integrated engagement framework (breach analysis, social baselines, etc.)	Consistent, transparent communication with stakeholders
Improving decision quality	BHP (portfolio-wide)	Standardised roles for Responsible Tailings Facility Engineer, Engineer of Record, independent reviewers	Clearer accountability and more consistent oversight

Note: all case study information in Section 3.1 is drawn from ICMM (2025), *Tailings Progress Report*.

The following subsections expand on these areas and case studies to illustrate how innovation is contributing to a changing risk landscape.

3.1.1 Strengthening the physical basis of safety

Anglo American (2025) is deploying technologies such as coarse particle recovery, novel leaching processes, and hydraulic dewatered stacking to reduce freshwater use and eliminate wet tailings. These advances enable drier, more stable tailings landforms and are being deployed across several operations in South America and Southern Africa to improve long-term tailings stability and safety of tailings facilities.

In Brazil's Pará state, Hydro (2025) is implementing full-scale dry backfilling to its bauxite tailings at Paragominas, achieving solids contents of at least 60% and placing material in mined-out area alongside more than 2,300 hectares of progressive rehabilitation.

These examples show how innovation in tailings conditioning and landform design can reinforce the physical foundations of safe, long-term facility performance, enhancing facility stability.

3.1.2 Re-thinking storage configurations to support long-term stewardship (ICMM 2025)

At the Sierrita copper mine in Arizona, Freeport-McMoRan is trialling more than 25 commingled blends of tailings and waste rock across 6 test pads to explore options for reduced footprints and improved stability of tailings facilities. At Paragominas, Hydro's dry backfilling also reduces dependency on conventional surface storage and moderates the scope of long-term care, enabling reclamation to progress alongside mining operations.

Together, these approaches illustrate different ways in which storage configurations can reduce long-term liabilities and support sustainable long-term stewardship.

3.1.3 Building transparency and trust through shared preparedness (ICMM 2025)

In northern Chile, Minera Centinela (a joint venture of Antofagasta Minerals with Marubeni Corporation), a copper-molybdenum operation, carried out a large-scale flood simulation with municipal authorities and Chile's disaster-response (SENAPRED), involving more than 400 residents. The simulation tested warning systems, evacuation routes and coordination between agencies, strengthening community confidence in the facility's emergency readiness.

Meanwhile, Rio Tinto's integrated engagement framework, combining breach analysis, exposure and vulnerability assessments, social baselines, and emergency preparedness across its global operations, provides a foundation for dialogue and transparent risk communication with affected communities across sites.

These practices highlight how transparent, participatory, evidence-based approaches can reinforce trust and shared preparedness – key components of effective risk management.

3.1.4 Enhancing clarity and coherence in operational decision-making

BHP has improved clarity and coherence in operational decision-making by standardising tailings governance in alignment with the GISTM and formalising key technical roles: the Responsible Tailings Facility Engineer, the Engineer of Record, and independent reviewers (ICMM 2025). Combined with structured engagement between the technical experts and Accountable Executive, and consistent review processes, this framework strengthens accountability, transparency, and risk-based decision-making across all their tailings facilities.

These governance innovations demonstrate how clearer roles, structured oversight and coherent information flows strengthen decision quality and risk management across tailings operations. ICMM member companies applying the GISTM are already observing clearer decision pathways and more consistent, risk-aligned judgements as these governance structures mature.

3.2 A shared information and response backbone

Many of the innovations described above rely on a shared information and response backbone that underpins all aspects of modern tailings stewardship.

Despite their diversity, many of the approaches highlighted above rely on a common information and response foundation. The ICMM's *Tailings Management: Good Practice Guide* (ICMM 2025) identifies tools such as InSAR, unmanned aerial vehicle/satellite imagery, fibre-optic sensing and in situ instrumentation as complementary components of modern surveillance, providing insights into facility performance. It also emphasises the importance of performance-based modelling, model calibration, digital-twin approaches and structured trigger action response plans to help improve early detection, calibrated response, and organisational learning. These elements are integrated within a tailings management system built on a plan–do–check–act cycle, supporting continuous improvement.

3.3 What these developments suggest – and the path ahead

Taken together, the innovations described in this section reflect a constructive shift in how mining companies understand and manage tailings-related risk, demonstrating how they are looking for opportunities across every aspect of tailings management. Across different contexts, these practices illustrate real progress in strengthening the physical performance of tailings storage, supporting long-term stewardship, deepening trust and shared preparedness, and improving the clarity and consistency of decision-making through innovation.

Section 4 builds on these insights by introducing reduce, re-use and re-imagine pathways in detail, including where each approach is most applicable, its maturity and the practical considerations for scaling from pilots to broader deployment.

4 Accelerating tailings innovation: from incremental improvement to transformational change

Maintaining safe, stable, and responsibly managed tailings facilities requires integrated and evolving practices. Innovation in tailings encompasses not just technology, but also outcomes-driven processes, supportive cultures, and enabling governance.

4.1 Why innovation must be central to the future of tailings

While traditional practices have strengthened significantly in recent years, their capacity for further incremental gains is becoming increasingly limited. Growing tailings volumes, driven by declining ore grades and increasing demand for minerals, are placing greater pressure on facilities that are becoming larger, more complex and expected to perform effectively over longer periods. At the same time, societal expectations are shifting; communities, regulators and investors are looking not only for evidence of safe performance today, but for credible long-term strategies that reduce future liabilities and environmental impacts.

In this context, incremental optimisation alone cannot keep pace with the scale of the challenge. Innovation must be understood not as optional or experimental, but as essential infrastructure for future mining. Emerging technologies, alternative processing routes, and new governance approaches are critical enablers that will allow the industry to move from managing risk at the margins to redesigning the system at its core. Innovation and enhanced collaboration offer pathways to reduce water and waste generation, develop inherently more stable landforms, strengthen real-time understanding of facility performance and enhance transparency in ways that build and maintain trust (ICMM 2022).

However, the next era of tailings management will not be defined by better dams alone. It will be shaped by fundamentally different ways of generating, managing and valuing waste. This includes reducing the volume of tailings produced, rethinking how materials are processed, and exploring alternative approaches that minimise or even avoid tailings generation altogether. Embedding new approaches across these areas is essential to achieving safer outcomes, supporting long-term stewardship responsibilities, and aligning the industry with society's expectations for responsible, sustainable resource development.

4.2 The tailings innovation landscape: what is already emerging

Typically, mine tailings exist as a liquid slurry of fine mineral particles created when ore is crushed, ground, and processed. However, across the industry, recent innovations now allow tailings to be used in ways thought impossible a decade ago. These advances are transforming tailings from a waste product into a potential resource, unlocking valuable metals and minerals previously overlooked – including materials that are gaining growing international attention as countries accelerate their energy-transition and critical mineral strategies (Sarker et al. 2022). Viewing tailings through circular economy principles and life cycle thinking clarifies where innovation can deliver value. In practice, innovation is being applied to: reduce the amount of tailings produced, re-use tailings already stored in existing facilities, and re-imagine tailings by moving beyond business-as-usual approaches.

Tailings innovation requires integrated thinking, decisive action, collaboration, and openness in sharing challenges and solutions, with the aim of mitigating environmental and social risks while creating opportunities to transform waste into value. This process is neither simple nor rapid. Solutions must be tailored to the specifics of each orebody, which vary across commodities, geographies, and even within a single deposit.

In 2018, ICMM members agreed to work collectively over 10–15 years to develop improved and cost-effective alternatives to conventionally managed tailings storage facilities that will reduce the risk of catastrophic failure (ICMM 2022), and are concentrating efforts to clarify where innovation can deliver value:

- Reduce – aiming to reduce fresh tailings through approaches such as effective dewatering (reducing fresh tailings volume), redirecting, and precision processing, which targets only the orebody to maximise ore recovery and minimise waste rock. Coarse-particle recovery further enhances efficiency by utilising the physical properties of ore and tailings.
- Re-use – seeking and creating value from existing tailings to minimise storage requirements and improve safe storage. Methods such as secondary recovery within a circular economy approach allow companies to valorise tailings, shifting them from a waste to a resource. But this approach is not a silver bullet: it should complement tailings risk reduction, improving overall safety and environmental outcomes by reducing the volume of tailings that pose risk, without shifting risks to future generations.
- Re-imagine – exploring breakthrough technologies that significantly reduce, and in some cases even eliminate, the production of fresh tailings through innovations across the value chain. While industry-wide elimination of tailings is not currently viewed as feasible, companies are working toward this goal within specific contexts.
- The following 3 case studies in Table 2 illustrate how these innovation pathways are already being applied in practice, showcasing operations that have reduced tailings at-source, re-used tailings within circular value streams, and re-imagined mining or processing routes to fundamentally change tailings generation.

Table 2 Illustrating reduce, re-use and re-imagine pathways in practice (ICMM 2024a)

Re-use	Reduce	Re-imagine
Newmont's CO_2 capture using tailings (Newmont 2023)	**Anglo American's technology to extract water from tailings (Anglo American 2023)**	**Antofagasta's leaching recovery of copper (Antofagasta 2022)**
Newmont, in collaboration with the National Laboratory of the Rockies – the US Department of Energy's primary national laboratory for renewable energy and energy efficiency research and development – is exploring using tailings for direct air capture of CO_2. This innovative approach could reduce both emissions and waste. Direct air capture technology uses special machines or chemical processes to remove carbon dioxide directly from the atmosphere. Once captured, the CO_2 can be stored safely underground or used in various products, for example, to produce carbon-negative concrete for infrastructure projects. This circular initiative helps reduce greenhouse gas levels while repurposing mining by-products.	Anglo American has developed an innovative hydraulic dewatered stacking (HDS) method, which has recently completed its initial testing phase in Chile. HDS has been developed to help Anglo American reduce its dependence on water and to create safer, more stable tailings facilities that can be remediated into dry and economically viable land after mine closure. This technology aims to reduce the volume of tailings by extracting water, which also allows for safer and more stable storage. By minimising water content, HDS also enables the recovery and re-use of water in mining operations.	Antofagasta has developed Cuprochlor-T®, a technology that extracts copper from primary sulphide tailings – finely ground waste rock that still contains unrecovered sulphide minerals. Because the Michilla mine in Chile used sea water with high chlorine levels, traditional bacteria-based extraction was not viable. Cuprochlor-T offers an alternative by using chloride salts and sulphuric acid to convert minerals into a form that can be more easily processed. After around 200 days, the method can recover over 70% of the copper, helping reduce tailings. The technology is now being tested at-scale and is seen as a potentially cost-effective way to make low-grade copper resources viable while reducing mining waste.

While these pathways illustrate promising directions for reducing, re-using and re-imagining tailings, their practical application remains highly dependent on technology maturity and site context. Across the industry, many emerging solutions still sit at low-to-mid technology readiness levels (TRLs), with only a limited number yet proven at demonstration or commercial scale. Factors such as orebody characteristics, water availability, geochemistry, regulatory constraints and integration with existing processing infrastructure strongly influence feasibility. As a result, pathways that appear technically attractive in principle may face scaling challenges – including energy demand, reagent use, capital intensity or long-term performance uncertainty. Recognising these constraints is essential; progress will require not only advancing individual technologies but enabling the conditions – data access, shared piloting environments, collaborative research and early engagement with regulators – that allow innovations to move from laboratory success to reliable, operational practice.

4.3 Bridging the gap between pilots and scale

While many promising technologies exist across exploration, processing, and reprocessing phases, the number that reaches high TRLs drops sharply. This is because the transition from laboratory success to site-scale deployment is fraught with structural, cultural, and operational challenges.

Mining, like many other industries, is risk averse. Tailings facilities and processing plants operate under stringent safety, regulatory and production requirements. Piloting new technologies often succumbs to inertia as new technologies, and operational requirements, can introduce:

- health and safety risks
- the possibility of production interruption
- integration challenges across tightly coupled processes
- potential impacts on regulatory approvals.

For many sites, these risks are perceived as too high, especially given the capital intensity of mining assets and their long operational life cycles. Even when technologies demonstrate strong potential, they often stall because the operational window for pilot testing is narrow and the tolerance for disruption is low.

Structural barriers add another lay of complexity, slowing innovation in several ways, including but not limited to:

- permitting and regulatory uncertainty
- complexity of integrating technologies into legacy infrastructure
- misaligned incentives between operators (focused on production continuity), suppliers (focused on technology rollout), and investors (focused on risk-adjusted returns)
- long-term liability considerations, which make operators more wary of unproven approaches
- market viability challenges, particularly when value propositions rely on non-traditional benefits.

Indeed, many of the benefits of tailings innovation, such as reduced closure liability, water savings, smaller long-term footprints, and improved post-closure land use are not captured in traditional business cases. As a result, promising technologies can be deprioritised simply because conventional (short-term) financial metrics do not reflect broader environmental and social value creation.

All of this underscores a critical point: innovation in tailings is as much a governance and collaboration challenge as it is a technical one. Successful deployment requires enabling conditions: shared risk models, supportive regulatory frameworks, coordinated piloting environments, and mechanisms that allow suppliers, operators, researchers, and funders to align on value.

Bridging this gap is exactly what ICMM's *Tailings Innovation Initiative* (TII) aims to address: creating a platform where evidence can be shared, barriers can be identified early, and technologies can be piloted safely and systematically. Through collaboration, transparency and collective problem-solving, the sector can move beyond the pilot project valley of death and toward scaled, system-wide transformation of tailings.

5 Collaboration as the engine of change: building a global tailings innovation ecosystem

Delivering the step change outlined in the preceding section will require more than technical advances alone. Progress depends on whether the wider system enables shared learning, coordinated effort and practical uptake of new approaches. Because tailings challenges cut across disciplines, jurisdictions and organisational boundaries, the industry must work together to turn emerging ideas into credible, scalable practice. This section explores how collaboration can serve as the engine of change, outlining the habits, roles and structures needed to build a global tailings innovation ecosystem.

5.1 Why no single actor can solve the tailings challenge: from isolated efforts to collective impact

The global scale of the tailings challenge is too large and too complex for any single organisation or technology to solve on its own. Tailings management brings together multiple disciplines – engineering, environmental science, social performance, and governance – and the way facilities are designed and operated directly affects community confidence and regulatory trust. Because no one actor holds all the expertise, data or practical experience needed across this full spectrum, progress relies on collective effort – including collaboration between companies to share learning and build collective knowledge in the industry (Figure 1).

Figure 1 The tailings innovation ecosystem

Real improvement requires operators, suppliers, researchers, regulators, and communities to each bring their unique knowledge and insights to the table, to develop solutions that are technically sound, socially credible and scalable across different regions and site conditions. ICMM's Innovation for Cleaner, Safer Vehicles (ICSV) initiative provides a strong example of putting this theory into practice, demonstrating how a neutral, problem-led collaborative can turn distributed effort into results which support different solutions pathways for its contributors – being technology agnostic is an important part of the recipe for success (ICMM n.d.).

The ICSV brings mining operators and equipment suppliers together in a non-competitive space to accelerate the development of a new generation of mining vehicles, while also creating opportunities for the improvement of existing technologies. The ICSV initiative sets 3 clear priorities: reducing diesel particulate exposure for workers in underground environments, advancing collision-avoidance technologies, and enabling greenhouse-gas-free surface mining vehicles – with shared roadmaps, site pilots and simple outputs that others can re-use. Its success, stemming from an emphasis on evidence and learned experience over opinion, shows that coordinated collaboration can move ideas from discussion to deployment. This model could very well be applied to tailings, as tailings risk is similarly a systems challenge, where collaboration is needed to move usable evidence, not just concepts, between sites, suppliers and oversight bodies.

The ICSV demonstrates 4 key habits that can be adapted to support innovation across the tailings ecosystem (ICMM 2024b):

1. Establishing a neutral convenor with a shared problem list. A trusted, noncompetitive forum helps maintain a live, prioritised list of the most important common challenges across the industry, which provides clarity on what matters, and on who is testing what, where.

2. Agreeing shared priorities and readiness-based piloting. Instead of focusing on technology alone, pilots are selected based on operational readiness and ecosystem integration. Simple playbooks outline prerequisites, operating conditions and common failure modes for various pathways and technologies, helping organisations choose the right pilots and scale only when conditions are met.
3. Developing simple, portable evidence. Knowledge is made easy to transfer through short, comparable case notes that capture context, what was tried and what was learned. Concise pre-reads and a shared repository ensure that evidence can inform practice, guidance and standards across sites. Site visits demonstrate how to put theory into practice, enabling fast followers to learn from early adopters.
4. Planning deliberate whole-system engagement. Progress depends on involving operators, suppliers, researchers, investors and regulators. Outcome-focused sessions address practical barriers such as data access or test protocols, while periodic sharing events highlight approaches ready for adoption to improve alignment on future work.
5. These habits offer a practical template for how the tailings community can turn distributed efforts into a coherent innovation ecosystem – one that accelerates learning, supports responsible uptake of new approaches and helps build trust across sites and stakeholders without prescribing a one-size-fits all approach.

5.2 Building the ecosystem required for tailings innovation

Progress will therefore depend on coordinated effort across the entire ecosystem, anchored by a neutral convenor that can align stakeholders, clarify priorities and guide collaborative action. Because tailings challenges span the full mining life cycle, a diverse set of actors must contribute, each playing a distinct role in enabling safe, scalable and circular solutions to scale:

- Mining companies act as first movers, providing sites, operational data and practical insight.
- Technology providers and suppliers develop and refine the solutions that make innovation possible.
- Academia and research institutions bring scientific rigour. They advance fundamental understanding of tailings behaviour and provide the independent testing, modelling and validation needed to de-risk emerging approaches.
- Industry bodies and neutral conveners create the pre-competitive space required for alignment. They coordinate shared roadmaps, support knowledge exchange, and help ensure evidence can move across companies and regions.
- Communities offer essential local knowledge and help ground innovation in social reality. Their participation builds trust, strengthens preparedness, and ensures new approaches reflect real community needs and expectations.
- Finance and investors influence which innovations reach scale by recognising value beyond short-term returns, such as reduced long-term liability.
- Policy-makers and regulators shape the enabling environment. Clear permitting pathways, aligned standards, and supportive regulatory frameworks reduce uncertainty and create the conditions for piloting and adoption.
- The broader value chain, including manufacturers, downstream industries and circular-economy partners, helps turn innovation into material circularity. By creating markets and demand for re-used or re-purposed materials, they transform tailings from waste into part of a continuous value loop.

5.3 Collaboration as a trust-building mechanism

Collaboration in tailings is not only about accelerating innovation; it is fundamentally about credibility. When companies work transparently with peers, suppliers, researchers, regulators and communities, they demonstrate a willingness to open their practices to scrutiny and shared learning. This transparency signals maturity: it shows that operators are actively engaging with others to understand risks, test assumptions and strengthen performance. In a context where past failures have profoundly shaped public perception, collaboration becomes a visible indicator of responsible intent, showing evidence that the industry is committed to learning, improving and acting with integrity.

Transparent collaboration also strengthens confidence among communities and regulators, helping shift the narrative to proactive, responsible stewardship.

5.4 From vision to delivery: the role of a dedicated tailings innovation initiative

Delivering innovation at the scale required to meaningfully reduce, re-use and ultimately re-imagine tailings demands more than isolated pilots or one-off projects. It requires a coordinated, industry-led effort with shared priorities, structured collaboration, and new partnership models that distribute both risk and value. The TII responds to this need; it provides a dedicated platform for ICMM members, technology providers, academia, investors, communities and policy actors to work together in a deliberate, pre-competitive environment, developing tools to enhance learning and competency, and providing forums to exchange knowledge and bring these different actors, shared problems and solutions together. To prevent future catastrophic failures and accelerate the reduction of conventionally stored tailings, innovation must be planned, coordinated and backed by sustained investment and leadership.

The TII aims to create continuity across the innovation life cycle, from shared roadmaps, structured pilots, and responsible adoption, to ensuring that knowledge, evidence and capabilities build over time, ensuring that insights are not siloed and reducing the risk of duplication of effort and unnecessary cost across the industry. Through structured engagement with technology developers and research institutions, the TII will align emerging solutions with industry-defined safety, sustainability and performance objectives. It will also help address systemic barriers by supporting better data access, enabling cross site testing where appropriate, strengthening regulatory dialogue and fostering shared learning across companies. In doing so, the TII will better enable pilot solutions and technologies to transition from fragmented experimentation to collective, long-term innovation stewardship, moving the industry from vision to delivery and positioning tailings reduction as a shared responsibility rather than a company-by-company endeavour.

Table 3 shows the key components of the ICMM's TII approach, which reduces the risk of repeated learning curves and stagnation, and helps companies and the wider tailings ecosystem to move faster.

Table 3 A structured framework to support collaboration through the ICMM Tailings Innovation Initiative

Framework component	What it includes
Inputs to the Tailings Innovation Initiative: what feeds the work	• Existing tailings roadmaps and standards • Industry experience and operational data • Research and academic insight • Technology innovation pipelines
Core innovation pathways: how innovation happens	• Reduce – minimise fresh tailings and water content • Re-use – safely create value from tailings where appropriate • Re-imagine – explore transformative alternatives to conventional tailings generation

Framework component	What it includes
Key enablers: what makes it possible	• Shared learning and transparency • Pilot and demonstration support • Independent technical input and constructive challenge • Regulatory and stakeholder engagement • Phased implementation (concept → pilot → adoption) • Regular review and recalibration
Intended outcomes: what this enables	• Inherently safer tailings systems • Reduced long-term liabilities • Increased confidence and trust • A stronger foundation for sustainable mining

6 Conclusion: turning shared commitment into lasting change

The future of tailings will be shaped by the choices the industry makes today. Progress is being made through stronger standards, clearer accountability, practical innovation and more deliberate collaboration, but these efforts could be expanded and accelerated. The industry is facing rising tailings volumes, more complex facilities and heightened expectations from communities and regulators. Meeting these challenges will require more than incremental improvement; it calls for a shift in how tailings are considered, managed and valued, supported by sustained leadership and commitment

Achieving this shift depends on the collective commitment of operators, suppliers, researchers, regulators and communities. No single organisation can solve the tailings challenge alone, but together the sector can build an innovation ecosystem that reduces risk, enhances transparency and strengthens long-term stewardship. The tools, capabilities and networks already exist; what is needed now is the resolve to apply them consistently and openly, and to share what works so that progress compounds across sites and regions.

The call to action is clear. We must continue to innovate, collaborate and lead with integrity. By doing so, the mining industry can help ensure that tailings facilities become benchmarks of responsible practice, not symbols of risk. If the sector chooses to innovate boldly and collaborate openly, it can redefine what is possible and ensure that the legacy of tomorrow's tailings is one of confidence, stewardship and trust.

References

Anglo American 2023, *Tailings of the Future: Hydraulic Dewatered Stacking (HDS) Completes Initial Testing in Chile*, viewed 6 February 2026, https://www.angloamerican.com/our-stories/environment/tailings-of-the-future-hydraulic-dewatered-stacking-hds-completes-initial-testing-in-chile

Anglo American 2025, *Minas-Rio's New Filtration Plant*, viewed 27 January 2026, https://www.angloamerican.com/our-stories/environment/minas-rios-new-filtration-plant

Antofagasta 2022, *Cuprochlor-T: An Innovation with Potential Industry-wide Implications*, viewed 6 February 2026, https://www.antofagasta.co.uk/media/articles/cuprochlor-t-an-innovation-with-potential-industry-wide-implications

Benchmark Source 2022, *More Than 300 New Mines Required to Meet Battery Demand by 2035*, viewed 27 January 2026, https://source.benchmarkminerals.com/article/more-than-300-new-mines-required-to-meet-battery-demand-by-2035

Data Bridge Market Research n.d., *Global Mining Tailings Management Market Size, Share, and Trends Analysis Report – Industry Overview and Forecast to 2032*, viewed 27 January 2026, https://www.databridgemarketresearch.com/reports/global-mining-tailings-management-market

Hudson-Edwards, KA, Kemp, D, Torres-Cruz, LA, Macklin, MG, Brewer, PA, Owen, R, … Thomas, CJ 2024, 'Tailings storage facilities, failures and disaster risk', *Nature Reviews Earth & Environment*, vol. 5, pp. 612–630, https://doi.org/10.1038/s43017-024-00576-4

Hydro 2025, *Tailings Management in Hydro*, viewed 27 January 2026, https://www.hydro.com/en/global/sustainability/our-approach/nature/tailings-management

ICMM n.d., *Innovation for Cleaner, Safer Vehicles (ICSV)*, viewed 26 January 2026, https://www.icmm.com/en-gb/our-work/cleaner-safer-vehicles

ICMM 2022, *Tailings Reduction Roadmap*, viewed 19 January 2026, https://www.icmm.com/website/publications/pdfs/innovation/2022/roadmap_tailings-reduction.pdf?cb=20771

ICMM 2024a, *Seven Ways ICMM Members are Exploring Innovative Technologies to Reduce Mine Tailings*, viewed 2 February 2026 https://www.icmm.com/en-gb/case-studies/2024/exploring-innovative-technologies-mine-tailings

ICMM 2024b, *The Art of the Possible: How Collaboration is Driving the Transformation of Large Haul Truck Fleets*, viewed 26 January 2026, https://www.icmm.com/en-gb/comment/2024/art-of-the-possible

ICMM 2025, *Tailings Management Good Practice Guide*, 2nd edition, viewed 6 February 2026, https://www.icmm.com/website/publications/pdfs/innovation/2025/tailings-management-good-practice-guide-2nd.pdf?cb=94652

ICMM 2025, *Tailings Progress Report: Implementing the Global Industry Standard on Tailings Management (GISTM)*, viewed 19 January 2026, https://www.icmm.com/website/publications/pdfs/innovation/2025/tailings-progress-report.pdf?cb=122644

Kahn, KB 2018, 'Understanding innovation', *Business Horizons*, vol. 61, no. 3, pp. 453–460, https://doi.org/10.1016/j.bushor.2018.01.011

Piciullo, L, Briseid Storrøsten, E, Liu, Z, Nadim, F & Lacasse, Z 2022, 'A new look at the statistics of tailings dam failures', *Engineering Geology*, vol. 303, https://doi.org/10.1016/j.enggeo.2022.106657

Mining Visuals 2025, *Unlocking the Hidden Value in Global Tailings*, viewed 27 January 2026, https://www.miningvisuals.com/post/from-waste-to-wealth-unlocking-the-hidden-value-in-global-tailings#:~:text=217%20km%C2%B3%20%E2%80%94%20The%20total%20volume,adopted%20by%20the%20industry%20include

Newmont 2023, *Newmont Partners with the NREL to Research the Use of Mine Tailings in Conducting Direct Air Capture of CO_2*, viewed 27 January 2026, https://www.newmont.com/investors/news-release/news-details/2023/Newmont-Partners-with-the-NREL-to-Research-the-Use-of-Mine-Tailings-in-Conducting-Direct-Air-Capture-of-CO2/default.aspx#:~:text=Newmont%20is%20pleased%20to%20partner,emissions%20throughout%20the%20value%20chain.%E2%80%9D

Sarker, SK, Haque, N, Bhuiyan, M, Bruckard, W & Pramanik, BK 2022, 'Recovery of strategically important critical minerals from mine tailings', *Journal of Environmental Chemical Engineering*, vol. 10, no. 3, https://doi.org/10.1016/j.jece.2022.107622