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Evolution of closure planning for an inactive tailings facility

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Abstract

Sustainable mine closure requires meeting physical, chemical, ecological, and social objectives. Sometimes, these objectives conflict with one another and pose challenges to mine-closure planning. This paper summarizes the key considerations for closure of a tailings facility with emphasis on recent Canadian Dam Association (CDA) and International Council on Mining and Metals (ICMM) guidance. It addresses movement and drying of saturated tailings; closure; final site grading; and water management. The paper also discusses how the approach to closure, landform design, and reclamation of an inactive tailings facility has evolved since initial closure planning began, incorporating institutional knowledge and best practices in dam safety and integrated mine closure. A robust closure plan requires winnowing the options to the most attractive solution and applying a multi-staged approach to closure—one that recognizes environmental stewardship is more than just minimizing potential impacts.

A brief case study of an in-progress decommissioning and closure project discusses how these principles are being applied. The case study also introduces the potential for economic benefit and resource gain for the surrounding communities through agricultural or natural-end land uses that will be considered as the design advances. The example demonstrates the benefit of reaching tailings dam sustainability goals that prioritize safety and environmental stewardship.

Keywords: *mine closure, reclamation, tailings, sustainability, landform design*

1 Introduction

The process of planning and implementation of mine closure and the post-mining transition has come into sharp focus for governments, industry, and the public as more mine closures are forecast, social consciousness rises, and investors favour more environmental, social, and governance (ESG)-forward companies. The global mining industry is undergoing a fundamental shift towards a sharper focus on adequate planning and design for closure and transition, as well as reconsidering what "sustainable closure" means. This paper will discuss key objectives associated with mine closure planning and implementation, with a focus on the decommissioning, closure, and reclamation for tailings storage facilities (TSF), which can pose environmental risk from residual waste if not properly managed. It will highlight some of the key components associated with successful closure as defined by global and North American best practice guidance, and how these objectives can come into conflict. It concludes with a case study of an in-progress design for closure of a recently inactive tailings facility.

Brock (2020) found that, of International Council of Mining and Minerals (ICMM) participating members, North America has the most forecasted mine closures within the next half-century. Correspondingly, Stevens (2021) noted that jurisdictions such as Canada and the US are on the leading edge of mine closure management, with several prominent regulatory and industry guidance documents that address the challenges and opportunities of modern mining. Examples are provided below with emphasis on commonalities and connectiveness of the ideas.

In 2013, the Mackenzie Valley Land and Water Board (MVLWB) in Canada issued the *Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories* (MVLWB 2013). In the guide, "sustainable closure" refers to the concept that successful closure and reclamation not only involves appropriate levels of engineering, (Indigenous) Traditional Knowledge, and science, but that stakeholders are comfortable with the outcome and play an active role in reclamation activities and post-closure monitoring. Four closure principles were identified for a project component (such as a TSF):

- Physical stability - ensuring it does not erode, subside, or move from its intended location under natural extreme events or disruptive forces to which it may be subjected.
- Chemical stability - chemical constituents released from the project components should not endanger human, wildlife, or environmental health and safety.
- No long-term active care - make all practical efforts to ensure that any project component that remains after closure does not require long-term active care and maintenance.
- Future use - site should be compatible with the surrounding lands and water bodies upon completion of the closure activities.

In 2018, the provincial government of Alberta (Canada) provided an update to a regulation in the provincial Water Act that included the release of the *Alberta Dam and Canal Safety Directive* (ADCSD) (Government of Alberta 2018). This document provides the requirements associated with initial permitting, construction, risk analysis, management, operation, and final decommissioning and closure for all dams (inclusive of TSFs) in Alberta. This document defines closure as:

> *"Closure means a process of modifying and establishing a configuration for a dam or canal with the objective of achieving long-term physical, chemical, ecological and social stability, and a sustainable, environmentally appropriate after-use…"* (Government of Alberta 2018)

These four critical aspects of sustainable closure (physical, chemical, ecological, and social stability) stated in this definition are similar to the principles identified in the MVLWB *Guidelines* (MVLWB 2013) and are further echoed in guidance from the International Council of Mining and Minerals (ICMM 2019) which defines the following "closure principles" in their 2019 *Integrated Mine Closure Good Practice Guide*: safety, **physical** stability, **chemical** stability, **socio**economic transition, **ecological** stability, and risk limitation.

The same four aspects are prominently included in the guides. MVLWB (2013) includes a focus on removing long-term care and embodies ecological and social stability in future use and ICMM further expands upon these to encompass safety and risk limitation; however, it can be argued that achieving stability in these four critical areas is essential to the principles of safety and risk limitation. These four components form the foundation of achieving sustainable closure, with physical and chemical stability being the critical pillars upon which objectives pertaining to other aspects can be accomplished. This hierarchy is presented visually in Figure 1, with sustainable closure shown as being supported by the four aspects critical to its success.

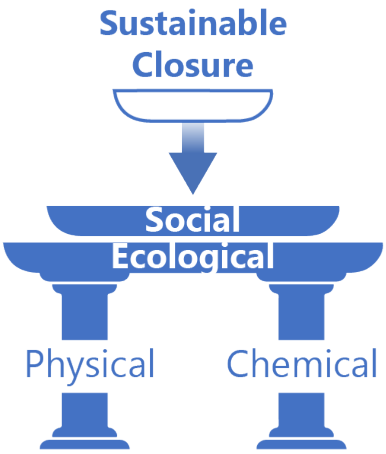

Figure 1 **Key aspects of sustainable closure**

Physical and chemical stability form the foundation for achieving sustainable closure because they are critical to long-term ecological and social stability. This is reiterated in the Nevada Bureau of Mining Regulation and Reclamation guidance document (State of Nevada 2020) pertaining to permanent closure plans where 1) long-term physical stability of any closure components must be provided and, 2) source stabilization must be provided to preclude the migration of any contaminant having the potential to degrade the waters of the state (chemical stability).

These four aspects sometimes conflict with one another, making planning for closure even more challenging. An example of this is a tailings or waste dump that contains potentially acid-generating (PAG) wastes and often becomes subject of debate for wet versus dry closure. One of the best ways to achieve chemical stability in such a situation is to isolate the material from air, which can be done by ensuring the material is kept saturated; however, this can be at odds with achieving physical stability, where saturated conditions can pose significant risks such as liquefaction, slope failures, and other similar geotechnical risks. Physical risks, such as erosion, can have significant consequences if not appropriately managed and planned for, given the time at which these closure landscapes are required to function (into "perpetuity").

This need to ensure physical and chemical stability is part of why closure nearly always involves a multi-stage approach and is most successful when it is completed over extended periods of time, ideally while the mine is still operating. Legacy facilities pose additional challenges to closure for several reasons, such as lack of equipment and lack of funding. This is why so many legacy mining facilities have fallen into public responsibility and have been left for the public to absorb the closure cost, usually greater than what it would have cost to complete had it been done progressively during active mining. Interests also differ significantly, and the need to achieve social stability as part of the final closure design for the facility means engagement with stakeholders is critical. These stakeholders can also be referred to as "communities of interest (COI)" with some examples provided by the Mining Association of Canada (MAC) in *Towards Sustainable Mining* (TSM) (2022): Indigenous peoples, community members, employees, neighbours, local governments, and non-governmental organizations (NGOs).

There may be more stakeholders than those given above, and this list is dependent on the site's location and ownership status. Engaging stakeholders as soon as possible in the planning process increases the likelihood of developing shared expectations about closure of these facilities.

1.1 Closure planning—aspiration versus realism

When thinking about closure planning for any element of a mining facility, the MVLWB (2013), ICMM (2019), and the more recent Society of Mining, Metallurgy & Exploration (SME) *Tailings Management Handbook* (2022) all refer to an overarching "closure vision". More than just meeting regulatory obligations, the closure vision should consider the mine owner's aspirations for the facility, including end land use, as well as how they want the facility's impacts on the environment and community to be perceived. Ideally, this is initially developed by the mine owner, but should also include input from the stakeholders described above to reach a shared vision of what the final end land use and outcome of closure will be. Each mine, and each element/component within it, is unique and requires that closure planning be appropriately tailored to its specific needs and challenges.

When developing this vision, it is critical that aspirations do not exceed realistic outcomes. Too often, a conceptual closure plan presented early in a mine life cannot be reasonably achieved. This can be due to both external and internal factors. These conceptual closure plans often have a lot of the "what" of closure (*"We are going to do this"*), but not enough of the "why" and "how" (*"Why is this the best option? How will we achieve it?"*). As a result, closure plans are presented to regulators and stakeholders as defined actions, but in a mine that may operate for decades, the mine plan, and therefore the mine closure plan, must inevitably shift. This can result in massive regulatory challenges and pushback from local communities. Therefore, it is critical to communicate the closure vision's intent and ensure it is shared with these stakeholders such that implementation changes still satisfy the overall objective. It is important to recognize that mines have a significant impact on the environment and communities in which they exist, and although these impacts can benefit global society and local economies, those benefits are usually temporary and come with a sometimes-significant environmental cost. Successful closure should not mean an exact return of land to its pre-mine condition, but rather toward an end land use that provides function and value to all stakeholders.

1.2 Closure planning for tailings storage facilities

TSFs are one of the most challenging mine-site elements to close. This is largely due to the challenging physical and chemical properties of the waste materials they store. Most mine closure plans call for some form of terrestrial reclamation; however, some mines (such as Alberta's oil sands surface mines) produce a fluid-like tailings material that is extremely weak and slow to consolidate and strengthen. Tying back to the pillars of closure—chemical and physical stability—tailings storage facilities often must undergo a transitionary step between active operation and final certified landform. While this step can have multiple phases, it is focused on transition of a TSF from a fluid containment structure (or "dam") into a physically stable structure, which behaves more like other mine waste structures such as overburden dumps. The CDA continues to review the dam safety guidelines for mining dams originally published in 2014, including an initial draft guidance in 2019 regarding an intermediary stage between an active dam and a landform—initially referred to as a mine waste structure—that was also summarized by the Alberta Energy Regulator (AER) (2020) in *Manual 019: Decommissioning, Closure and Abandonment of Dams at Energy Projects.* The criteria defined in *Manual 019* are focused on whether water and contents contained within the TSF can be considered "fluid-like" or "flowable", and whether they require a containment structure to avoid an uncontrolled release. This guidance continues to evolve, and the CDA Working Group on Non-Dams is considering replacing the term "Mine Waste Structure" with "Tailings Stack" to better differentiate between tailings storage facilities that no longer contain flowable tailings, and other mine waste storage structures (such as an over burden dump). This phase of closure for a TSF is a purely technical one, where the objective of this transition period is to create a structure that is physically stable. A key distinction in TSFs is that this reference of physical stability does not just apply to the associated containment structure, but the contents contained therein. Figure 2 presents a visual presentation of the potential progression through closure of a TSF in Canada.

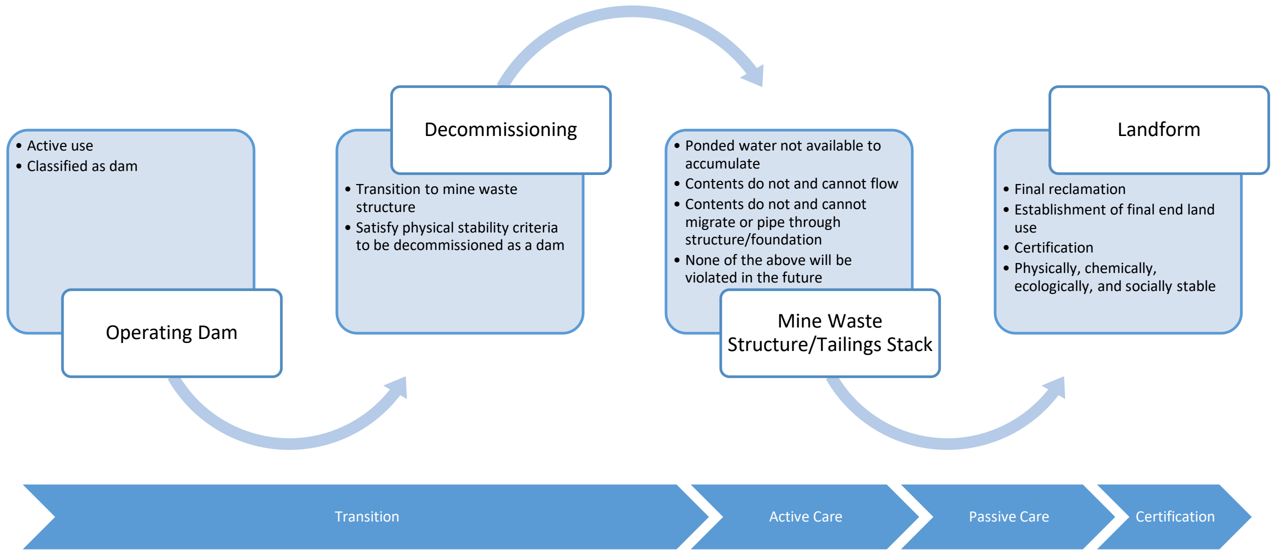

Figure 2 **Phases of closure for a TSF in Canada (modified from Al-Mamun & Small 2018, and Schafer et al. 2019)**

The following sections of this paper present a case study of a TSF closure and water management infrastructure project currently undergoing detailed planning for its transition from an operating dam to a mine waste structure. It will discuss the transition from a mine waste structure to a landform that will develop and accomplish end-land-use objectives defined by the owner and stakeholders for the facility over the long term.

2 Methodology

This paper emphasizes some of the information from the guidance presented above through a case study focusing on the closure planning for an inactive tailings storage facility in North America. Given the mining operations have been ceased for some time—and there are no waste dumps or pits to reclaim—it focuses on closure and reclamation of the TSF and water management systems still in use. The summary presented in this paper is a simplified version of a detailed design basis memorandum (DBM) advancing through regulatory review and stakeholder engagement with the proposed closure configuration. Development of this plan largely focused on guidance provided by local regulation, and national and international guidance and best practices as defined by the CDA (2013, 2014), Alberta Energy Regulator (2020) and ICMM (2019) and discusses the options for closure that were considered. It summarizes the anticipated advancement of the preferred option from an active tailings facility to a mine waste structure, and finally to a landform that meets the long-term goal of physical, chemical, ecological, and social sustainability.

3 Case study: planning for closure of an inactive tailings facility

A case study of an inactive tailings facility formerly used to manage tailings from an underground mine highlights the application of the guidance discussed above to a real-world example. It will provide a summary of the considerations for closure and management of residual waste materials within the tailings facility, culminating in a feasibility-level design basis for the site.

3.1 Project background

The project site is a former underground mine that operated in the late 20th century before the end of mining operations and associated flooding of the underground mine workings. The TSF and associated surface and underground water management infrastructure manage process-affected water at the site as well as several nearby sites in the region. The facility includes a roughly 30–hectare (75–acre) synthetically lined TSF that managed both tailings and process-affected water from the site during active operations and beyond. The

TSF is contained by a side-hill earthen dam structure with a maximum height of approximately 15 meters (50 feet) that bounds half of the TSF perimeter, with the balance contained by the natural topography. The majority of the TSF area is unsaturated and covered with residual waste materials left as a byproduct of the mining process, with the balance (approximately 3 hectares) maintaining a pond to manage stormwater and seepage. In addition to the TSF, the site also includes a system of drainage and runoff ditches connected to two synthetically lined ponds for the purpose of surface water management, including process-affected water. Remaining infrastructure includes pumphouses associated with water management on the site and an administration building. A portion of the subgrade under the TSF contains process-affected groundwater; this water is captured and managed by a subsurface interceptor drainage system that collects groundwater from below the TSF and prevents its movement into nearby natural freshwater sources. The process-affected water referred to in this paper contains a high concentration of ions and may pose challenges to ecological restoration and plant establishment. No other major contaminants of concern (COCs) have been associated with this water.

Figure 3 presents a simplified layout of the site discussed in this case study, with key water management elements and facilities shown.

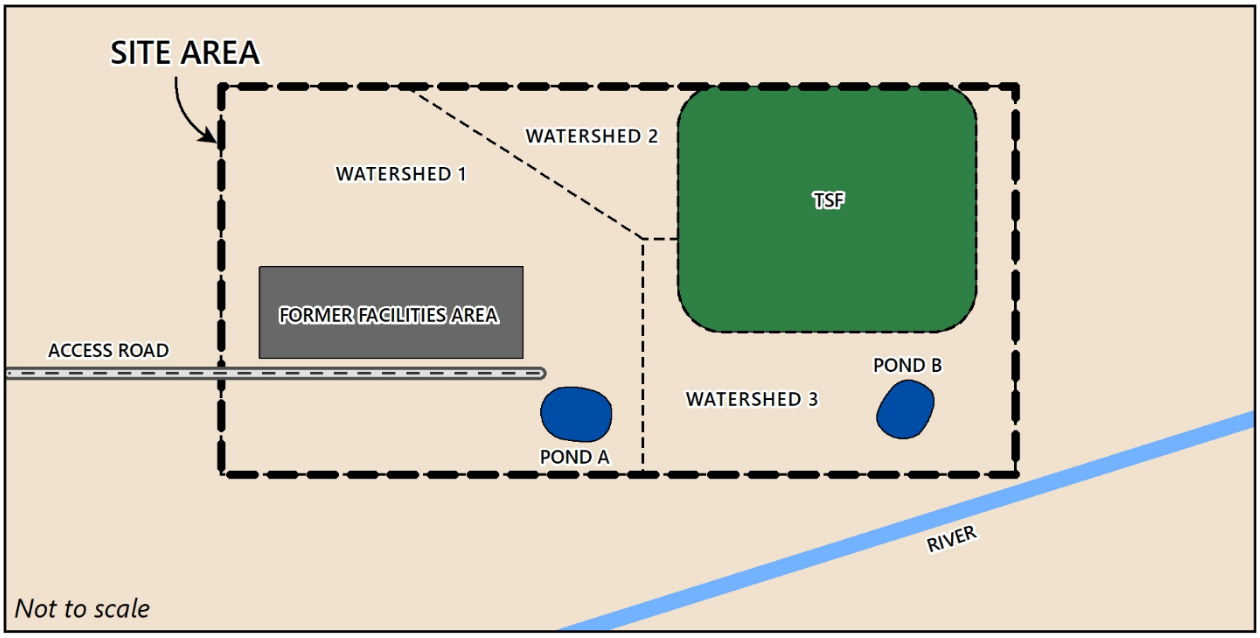

Figure 3 Case study site layout

3.2 Closure considerations

Closure planning for the site primarily concerns placement and isolation of residual waste materials within the TMA, improved site-wide water management to remove the needs for the TSF, and eventual decommissioning and removal of the existing earthen containment dam. This will accommodate construction of a new permanent landform which will provide a beneficial end land use for local communities and the site owner. The objectives defined for the closure and reclamation of these facilities are as follows:

- Provide a setting that is environmentally compliant (e.g., chemically stable) in the long term.
- Provide a setting that is physically stable in the long term (e.g., not subject to liquefaction and flow).
- Return the site to a sustainable end land use, either as a natural landform or other identified beneficial reuse for the land.
- Minimize long-term liability associated with residual waste materials at the site.
- Provide an efficient solution for closure and long-term land stewardship.

Achieving these objectives depended on two key facets of the site: appropriate disposal/management of the remaining mining waste onsite, and management of surface and groundwater.

3.2.1 Residual waste management

Selecting the best method of disposing/isolating the residual waste materials was the first critical aspect considered in the conceptual phase of design for closure of this facility. The current phase of design estimates that approximately 230,000 to 300,000 cubic metres of very soft waste material will require management. These waste materials—comprised primarily of silts, clays, and non-acid generating (NAG) waste rock—are not considered hazardous. However, because they are fluid-like and impacted by the process-affected water, they must be suitably managed to minimize risk to the surrounding environment.

One of the initial disposal options identified was drying and offsite disposal (such as at a designated landfill or other suitable location). This was dismissed for several reasons, largely due to a lack of suitable locations nearby, as well as the quantity of material requiring disposal. In addition to these mechanical limitations, it was also noted that movement of this quantity of material would require a significant trucking effort that would be disruptive to local communities due to the need to use public roads and create unnecessary air emissions.

Disposal of the affected waste materials was therefore determined to be best managed within the site area. One of the first options considered was disposal in the existing underground mine workings; specifically, the mine shaft. Although it was determined technically feasible based on available volume for storage within the mine shaft, this option was dismissed due to operational challenges associated with excavation, transport, and placement of the wastes inside the mine shaft, as well as significant environmental concerns associated with groundwater impacts from placing the waste below the groundwater table.

The remaining disposal option was on the surface within the extent of the mine lease. Two options were reviewed: storage outside the current TSF area, or storage within the existing TSF area. Given this was formerly an underground mine, storing the wastes outside of the TSF would have created additional disturbed areas that would need to be reclaimed and could pose additional environmental risk. The most suitable location to construct a permanent repository for these materials was determined to be within the TSF footprint. For final placement within the TSF area, two options were considered: consolidating the tailings in place (requiring much less rehandling) and placing the materials in an unsaturated tailings structure. Consolidation in place was deemed infeasible due to concerns regarding physical stability (e.g., long-term liquefaction potential). This approach would also have been more difficult to integrate into the surrounding landscape and retained greater long-term risks associated with the geotechnical properties of the retained tailings. Ultimately, excavation and placement in a dry mine waste structure/tailings stack were determined to be the best option for permanent disposal and sequestration of the residual waste materials within the TSF.

This option would involve excavation, drying, and placement of all residual wastes within a sealed element contained by an impermeable synthetic barrier on the top and bottom to prevent interaction with natural water systems. This option is highly attractive because it minimizes the need for long-term active care associated with waste and contact water and in minimization of risk. Two areas were considered for this landform element—one on the topographic high side of the TSF (representing an upgradient location relative to groundwater flows), and one along the current earthen containment dam. The approximate locations for the upgradient and downgradient waste impoundments are shown in Figure 4 along with surface water flow direction.

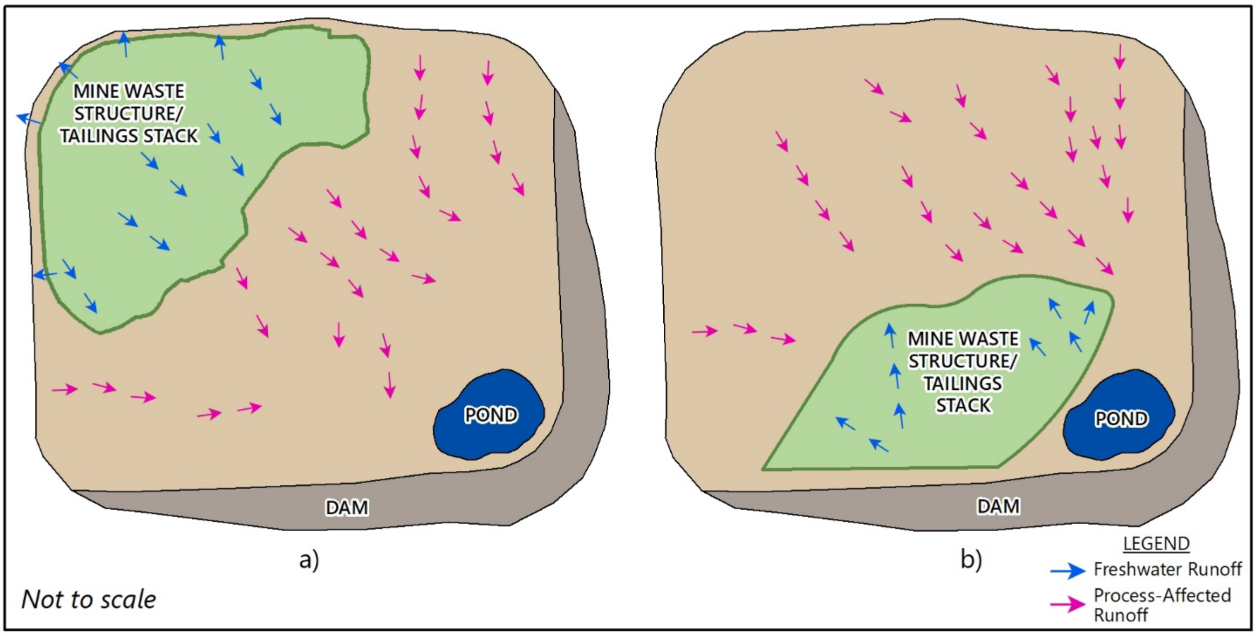

Figure 4 **Options for final waste material placement in the (a) upgradient and (b) downgradient areas of the existing TSF area**

The upgradient configuration was chosen based on the advantages to the final closure and reclamation design for the facility (e.g., natural landform analogues), as well as environmental protection and operational efficiencies. These were primarily the results of the residual materials being placed in a "high and dry" location relative to groundwater flows and topography, which lowered the risk of pooled water and interactions with the natural groundwater systems. This also avoided using the existing dam for containment purposes, facilitating improved stability and risk reduction and allowing for the continued use of the downgradient portion of the TSF area for process-affected water management during the second closure stage. Mine water management and the overall approach to closure and reclamation for the site are discussed in later sections of this paper.

3.2.2 Mine water management

Responsible management of process-affected water on site is critical to the proposed closure approach. Figure 5 presents a high-level layout of the key water management systems currently in place at the site.

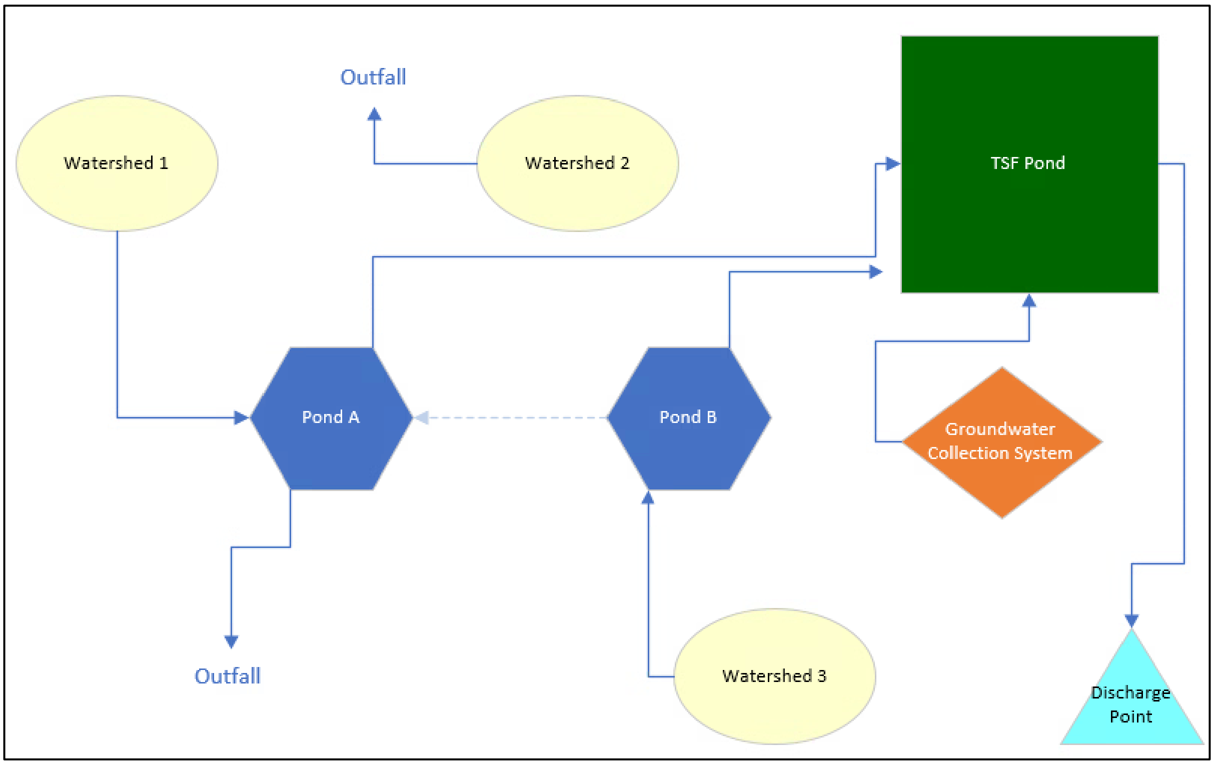

Figure 5 Simplified mine water management configuration

This site has a unique feature. The collected process-affected water can be transported and discharged directly to a water body with properties like that of the water that is captured and managed on the site ("discharge point" shown in Figure 5). As a result, water stored in Pond B and within the TSF can be removed from the system and discharged as it is captured, with a delay to balance outflow volume restrictions.

Currently, most water on the site is captured and managed using two small surface-water ponds and a portion of the TSF area along the earthen containment dam. The proposed closure design focuses on remediation of the surface and shallow groundwater systems on the site such that direct discharge of surface runoff to the environment is safe and remaining groundwater captured during the post-landform construction period can be transported and discharged directly to the approved water body rather than requiring storage on the site. Currently, water from Watershed 1 is routed to Pond A to ensure the captured water meets water quality requirements for discharge to the nearby water source. Monitoring to date has not indicated any exceedance, and most water collected in Pond A from Watershed 1 is safely discharged to the natural water source. The system allows for water transfer from Pond B to Pond A, but this is used very rarely given the elevated electrical conductivity for the water captured in Pond B.

The early stages of closure planned for this facility include continuous monitoring of water levels of the receiving water body such that Pond A can be fully decommissioned and removed, with surface flows from Watershed 1 being allowed to discharge to the environment permanently. It is assumed that Pond B and storage within the TSF will remain operational until the final stages of closure, when the remaining surface water management infrastructure is removed, and the final landform is constructed. This will allow for the continued capture and management of process-affected surface and ground water while the landform element containing the residual waste materials is constructed. This staged approach also allows for the gradual removal of more of the watershed areas outside the TSF area that contribute to Pond 2 and the TSF as the water quality improves. This will further reduce the liability and operational challenges associated with managing these quantities of water, which in turn will facilitate the eventual complete removal of all surface water management infrastructure on the site. Resolution of the process-affected groundwater deeper below the surface of the TSF is assumed to require additional capture and discharge for a longer period, and the staged closure design accounts for this need.

3.3 Closure design

To achieve the desired closure outcomes, closure for the subject mine site was split into three primary stages focused on risk reduction through decommissioning of the TSF, surface and groundwater management, residual waste management, landform construction, and reclamation to the selected end land use:

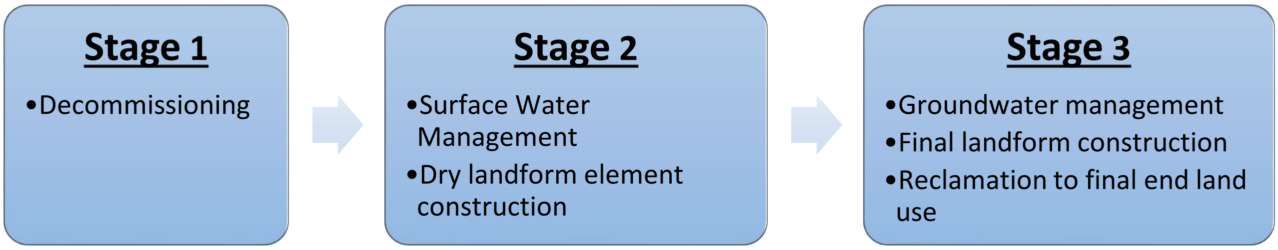

Figure 6 **Three stages of mine closure**

The decommissioning stage has been in progress for several years, and during that time the owner has primarily been concerned with demolition and removal of plant infrastructure, water management, and residual waste management activities. Final design activities and initial closure are occurring in parallel as the facility transitions to the second stage of closure.

The primary objectives of Stage 2 are to modify the ground and surface water management systems such that the management burden for surface water at the site can be reduced and eventually eliminated, and the residual waste materials can be excavated and placed in their final storage location. Achieving long-term physical and chemical stability on the site relies on eliminating the need for the earthen containment dam structure as well as routing water away from site storage for direct discharge to the environment in accordance with water quality requirements.

In addition to the water management modifications, the most significant construction associated with the wider closure plan is anticipated to be that of the permanent landform element containing the residual tailings waste. As discussed above, the location for this element was determined based on its location on the topographic high of the TSF and compatibility with the closure objectives. Containment is to be achieved using compatible synthetic impermeable liners (such as HDPE) to encase and isolate these materials from the natural environment indefinitely.

To improve physical stability of these waste materials, they will first be excavated and partially dried via placement in cells where natural evaporative and drainage processes can reduce their water content and improve their geotechnical characteristics. The fines-dominated material will be blended with the NAG waste rock before final placement in this sealed landform element. The size and shape of the landform was determined based upon the estimated volume of material requiring storage, and local analogues for slopes and general shape. This resulted in a footprint of approximately 11 hectares, and an average overall slope from crest to toe of 4%. This is in alignment with the topography surrounding the site which ranges from 3% to 5%. This slope was chosen due to its lower risk of significant erosion, robust stability, and fit into the surrounding environment. The cover is anticipated to be constructed as shown in Figure 6. The cover design requires limiting infiltration to the extent practicable and providing suitable growth medium for the probable end land use. Therefore, the cover has been designed to include a low-permeability layer (geomembrane in this case due to the absence of local clay borrow) with suitable cover soils to prevent exposure of or damage to the geomembrane and to support establishment of vegetation. A protective layer has been included above the residual waste to isolate the geomembrane from the residual waste which may contain some angular rock. The first few layers will be constructed during Stage 2 and the final cover, including topsoil and rooting soil, will be constructed in Stage 3 using remaining fill material salvaged from the existing earthen dyke. The intermediary closure surface may be seeded with light grasses but will mostly be managed to minimize erosion and prevent accumulation of water on the surface of the landform element.

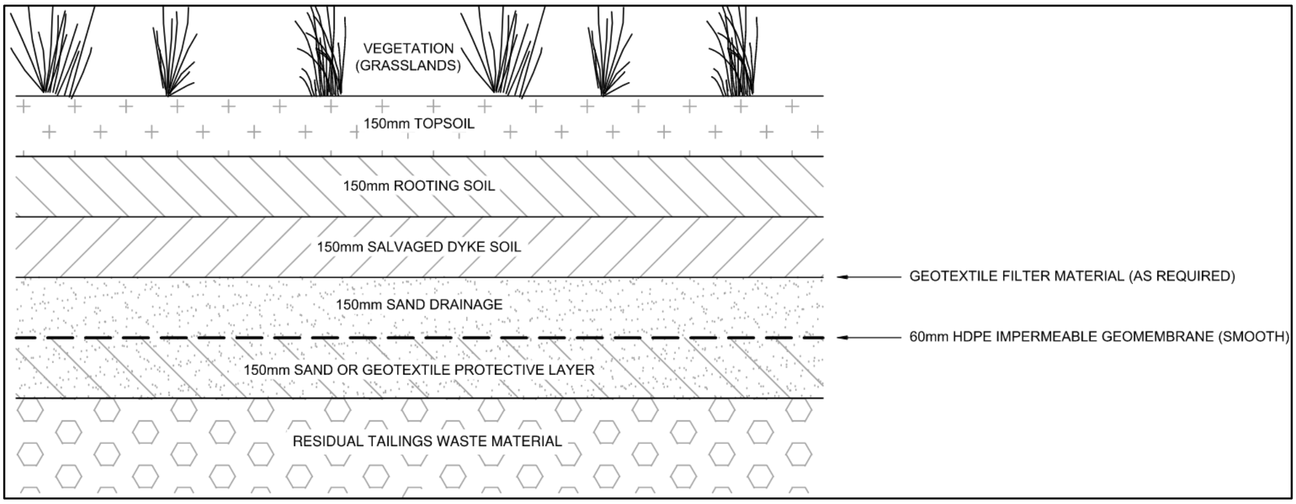

Figure 7 **Residual waste material storage landform element cover**

To speed the process of "washing out" the shallow groundwater system impacted by the compromised liner inside the TSF, an opportunity to take advantage of clean rainwater from the surface of the constructed waste storage element was identified. To this end, a shallow drainage ditch will be constructed along the downstream toe of the waste landform element to encourage infiltration of clean freshwater flows through the shallow groundwater system, reducing the ionic load and cleaning up the shallow soils inside of the TSF area. This is critical to permanent removal of the water storage area inside the TSF and eventual removal of the containment dyke. Because the length of time between Stage 2 and the end of Stage 3 is dependent on improvement of groundwater quality to a level where it no longer poses a risk to the surrounding environment, this presented an opportunity to implement closure actions that address more than a single objective (i.e., physical and chemical stability). The impact of the shallow drainage ditch will be monitored and can be optimized throughout Stage 2. Figure 7 provides a three-dimensional illustration of the TSF area at the end of Stage 2. The residual waste-storage element and the remaining water-storage area is shown in the top and bottom of the figure, respectively.

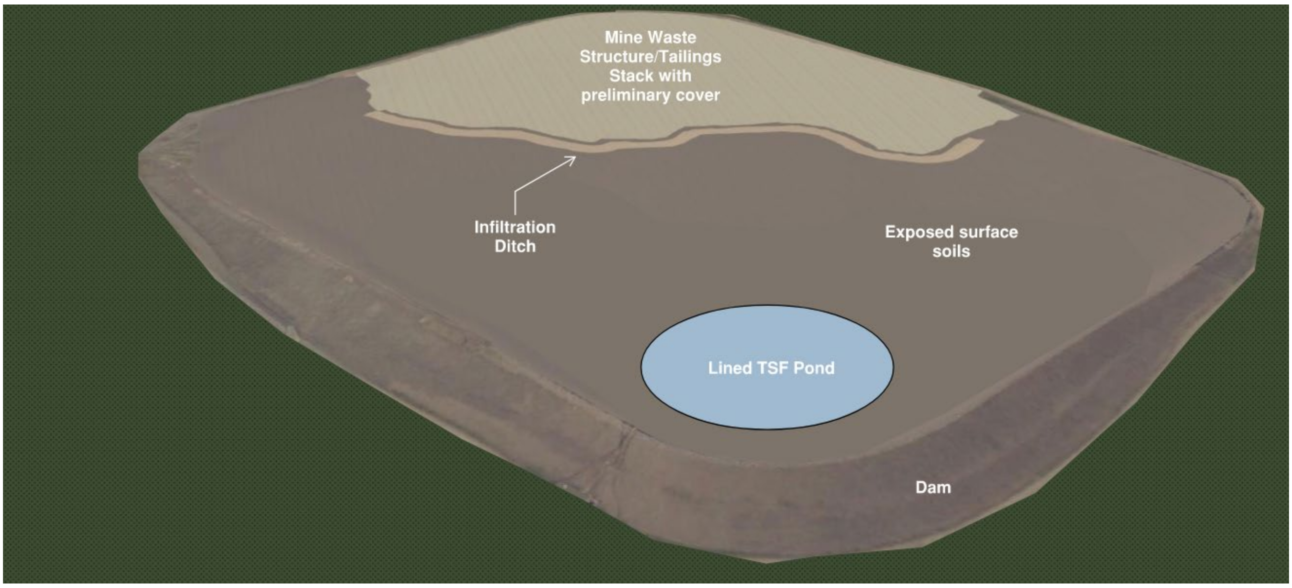

Figure 8 **TSF configuration at the end of Stage 2**

Stage 3 represents the final stage and prepares the site for its transition to its final end land use. The primary construction occurring in Stage 3 includes demolition and removal of the containment dyke and associated pond management infrastructure within the TSF. The remaining dyke structures will be removed, and the recovered material will be used for construction of the final layers of the residual waste-storage landform element cover, surface restoration, and final infill/grading of the TSF footprint. At this point, the TSF facility will transition fully from an operating dam configuration to that of a mine waste structure that can then be reclaimed and shaped into its final landform. Topsoil will be placed over the final reclaimed surface before being revegetated according to the end land use. The configuration of the TSF area at the end of this phase under an assumed natural end land use is provided in Figure 8. It is anticipated that this final end land use continues to be refined during the next stage of design, but the current options determined to be the most suitable and advantageous for the site include agricultural or natural land uses.

The final phase of Stage 3 includes a period of active monitoring and care of the reclaimed TSF and surrounding areas and follows the creation of the final closure landform. During this phase, the groundwater capture system will continue to operate until resolution of the high ion concentrations in the groundwater below the TSF. This process is anticipated to take years to decades to complete. At its conclusion, the groundwater system will be shut off, and any remaining infrastructure will be removed/abandoned in accordance with the final selected end land use for the site. Currently, restoration to a natural end land use is planned at the conclusion of the monitoring period as illustrated Figure 8. However, given this period of monitoring could last for an extended period, it is possible that beneficial reuse of the final landform may be considered, such as agricultural activities. It would be advantageous (aspirational) to have uninhibited use of the surface of the landform, but the residual waste repository will need to be protected and may limit the surficial vegetation options available for the final cover (such as limiting to shallow rooted species). Future work will include engagement with surrounding communities on the end land use and the relative benefits of the various natural and agricultural reclamation options.

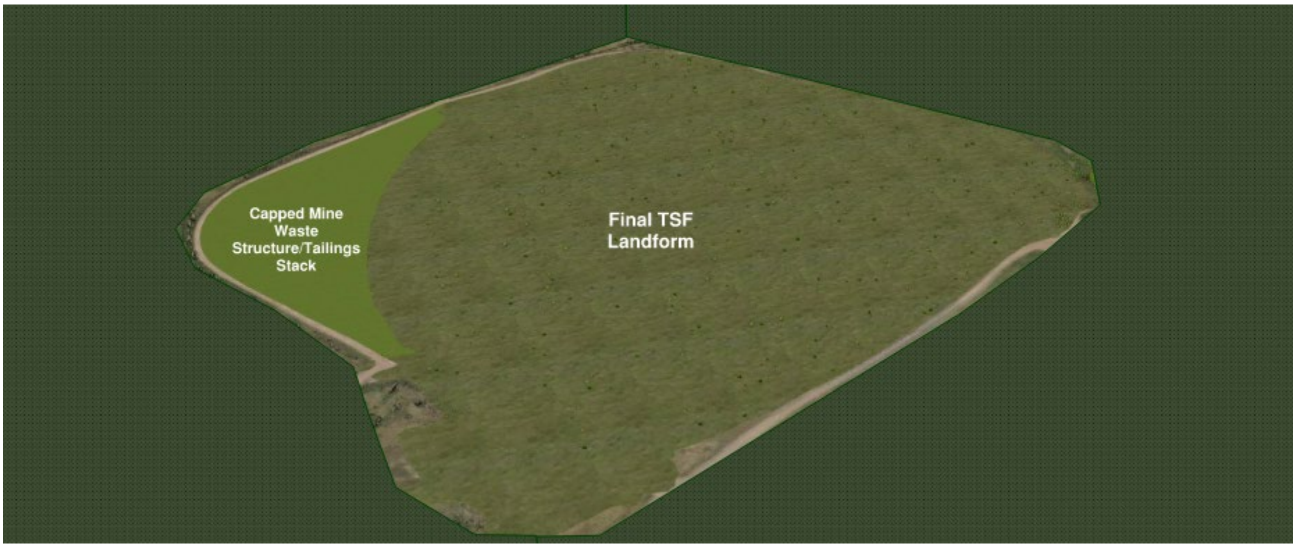

Figure 9 Final TSF landform configuration – natural end land use shown.

Although the case study presented in this paper has proposed a detailed design basis for closure of the subject mine site, it is important to acknowledge that planning and design for closure is an evolving process. Determination of final end land use will continue to be developed in consultation with local stakeholders and communities, both through the final design process and during active closure management activities in Phases 2 and 3. The needs and value of the reclaimed land to stakeholders may evolve, and consideration must be given to ensuring that the final end land use brings value to local communities and ensures risk to the public is as low as reasonably practicable when it is certified and returned to the local community. Selection of end land use will be further advanced during the final stage of design for closure of the facility and will likely include some or most of the site being returned to a natural state in alignment with the native flora and fauna that make up the surrounding ecological landscape.

It should be noted that the closure approach for the case study presented in this paper is currently under review by local regulators, and further changes and modifications to the approach to closure for the facility are possible. This evolution will be driven by best practice guidance, stakeholder engagement, owner objectives, and regulator feedback to ensure the best closure outcome possible for the facility over the long term.

4 Conclusions

The paper has presented critical considerations in the closure of TSFs in select areas of Canada and the United States as well as application of key guidance to an existing inactive tailings facility. In general, adequate closure planning and implementation during mining and the post-mining transition are becoming a growing focus for government, industry, and the public at large. With a greater quantity of current and legacy mining facilities expected to enter various stages of closure in the next several decades, investors are favouring ESG-forward companies. Demonstration of good mine closure practices on existing or legacy mines can also have the benefit of improving likelihood of future approvals with regulators for the opening of new mines or expansion of existing ones. For each guidance example summarized in this paper, closure plans must provide physical and chemical stability, which is required to ensure wider aspects such as social and ecological stability.

All mine sites (and even elements of specific sites) are unique and therefore require a unique closure approach. The site discussed in this paper included management of soft waste material with elevated electrical conductivity process-affected water that required special consideration to establish physical and chemical stability. This was determined to best be achieved through a dry stacked-closure approach combined with ongoing mine water management to meet the defined closure objectives. A staged closure approach provides continuous de-risking and environmental improvement of the site, with the goal of moving to a facility in a long-term passive-care state. It considers innovative approaches to accelerate groundwater improvement through repository construction and specific surface water routing designs. These key technical considerations are being prepared in consultation with ongoing stakeholder engagement and regulatory oversight to ensure social stability of the closure configuration for the site.

The site examined in this case study is relatively small compared to many global mining operations, with a small quantity of waste materials to manage permanently, and even it requires careful consideration for the challenges posed by closure of this site. Considering the aspects of closure discussed earlier in this paper is critical to high-quality, sustainable closure of both current and legacy mining facilities. Pending regulatory approval, the closure plan for the tailings facility presented in this paper will be advanced to final stages of design. This will include further refinement of the design for the mine waste structure/tailings stack and final landform in addition to the determination of the best end land use to ensure long-term stability for the site and bring long-term value to the land for surrounding communities.

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