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Mine closure and reclamation planning —

Part 2: **Guidance**

Planification de la fermeture et de la restauration des mines —

Partie 2: Lignes directrices

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents shall be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 82, *Mining*, SC 7, *Mine Closure and Reclamation Management*.

Introduction

Part 2 of ISO 21795 provides guidance for mine closure and reclamation planning applicable to both new and operating mines. The overarching objective is to promote consistency and quality in planning for mine closure and reclamation internationally. The first part of the document (ISO DIS 21795-1) provides requirements for the same material.

The intended audience are those with responsibility for, or an interest in, planning for mine closure and reclamation. This includes mine planners and designers, mine operators, regulators, environmental assessors, local communities, Indigenous Peoples and financial stakeholders, amongst potentially others.

Early, continual and comprehensive mine closure and reclamation planning is essential for all new and operating mines because it:

- Leads to the highest degree of environmental and social success, usually at a lower cost than if mine closure and reclamation planning is not done from the beginning of the mining project;
- Reduces risks and liabilities throughout the mine's operational life and on closure;
- Allows for stakeholder involvement throughout, so that relevant knowledge and understanding are brought into the planning process;
- Allows for devoting more attention to sustainable development activities identifying socio-economic opportunities for the various closure phases;
- Helps build trust with governments, stakeholders and international communities;
- Provides additional planning time to understand the complexity of the biophysical characteristics and socio-economic context of each mine site;
- Provides for continual improvement and updating of closure and reclamation plans;
- Allows companies to better integrate closure and reclamation activities with operations;
- Provides time to identify, research and develop new technologies for mine closure strategies and mine closure treatments that increase robustness and resilience of mine closure and reclamation; and
- Allows companies to better provision for and schedule closure and reclamation funding.

There are many leading practices and guidance documents related to mine closure and reclamation planning available in various jurisdictions and used by many mining companies and stakeholders. This document captures the intent of such guidance documents so that it can be applied globally.

Mine closure and reclamation planning —

Part 2: Guidance

1 Scope

This document provides guidance related to the necessary planning activities for new and operating mines.

Recommendations are provided on:

- Closure and reclamation of mine site, including:
  - Tailings storage facilities
  - Water storage facilities
  - Waste rock management facilities
  - Heap leach facilities
  - Open pits
  - Underground workings
  - Mine infrastructure
  - Temporary closure
- Land reclamation and water management, including:
  - Landforms
  - Surface preparation
  - Vegetation establishment
  - Water management
  - Covers
  - Climate change effects
- Stakeholder engagement, including:
  - Objectives
  - Approach
- Decision and analysis tools, including:
  - Design levels
  - Alternatives identification and analysis
  - Designing and operating for closure and reclamation
  - Risk assessment and management

- Cost estimating
- Performance monitoring and reporting
- Adaptive management
- Application to the long-term care phase

This document does not provide detailed survey methods, testing or monitoring methods, detailed engineering procedures, detailed product requirements, or detailed construction and operational procedures. Occupational health and safety issues related to mine closure and reclamation construction are also excluded from this standard. Exploration activities are also excluded from this document.

This document is not intended to be used for the closure and reclamation of abandoned mines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

International Council on Mining & Metals *Adapting to Climate Change*

ISO/DIS 20305, *Mine Closure and Reclamation Vocabulary*

ISO 9000:2015, *Quality management systems — Fundamentals and vocabulary*

ISO 31000:2018, *Risk management — Guidelines*

ISO 14001, *Environmental management systems — Requirements with guidance for use*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO DIS 20305 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Closure and reclamation of mine site

4.1 Tailings storage facilities

4.1.1 General

Tailings storage facilities (TSFs) are frequently amongst the largest and most complex facilities to close and reclaim. Since they also frequently involve the long-term storage of millions of tonnes of potentially liquefiable finely ground materials and large water volumes, they can represent the highest risks at a closed mine site; a catastrophic failure of the containment dam can lead to loss of human life and extensive, irreversible environmental damage. The structures retaining the tailings are typically engineered dams that rely on sound foundations and internal drainage systems to remain stable; they therefore require sophisticated long-term care programs, including professional engineering oversight monitoring, inspections, and maintenance.

It is also important to note that the design criteria, such as geotechnical criteria for confirming dam stability (e.g. the design earthquake) and hydrological criteria (e.g. inflow design flood volumes and peaks flows) at a TSF may have to be augmented at closure. This is because the closure period is much longer than the operating period and more stringent design criteria with lower frequencies of occurrence are needed to reduce the annual probabilities of failure to a reasonable value for the long-term closure period. This may require additional engineering measure to be installed, such as dam support buttresses and larger spillways.

4.1.2 Objectives

Specific long-term objectives for the closure and reclamation of a TSF include:

- The closed TSF should be non-polluting;
- Tailings disposal structures should remain physically stable with regards to both overall stability of the major structures and erosion resistance;
- Long-term maintenance requirements should be minimized; and
- Suitable design criteria should provide for an acceptably low risk over the long-term.

4.1.3 Approach

The following clauses describe what actions should be undertaken for the preparation of closure and reclamation plans and designs for a TSF:

- Assessment of the status and condition of the TSF;
- Risk assessment of the TSF;
- Closure and reclamation alternatives analyses; and
- Closure and reclamation plan.

4.1.4 Status assessment

The status and condition of the TSF should be known in order to complete an effective closure and reclamation design. During the mine planning phases, the TSF does not exist and its design can serve as a basis for the closure and reclamation design. During operations and prior to the implementation of closure and reclamation, the condition and status of the TSF should be determined.

Information required to determine the TSF status and condition includes the following:

- TMF site geology and hydrogeology;
- Design drawings and specifications or “as-built” details, drawings and construction QA/QC results;
- Predicted and actual physical and geochemical characteristics of the tailings;
- Predicted and actual water balance of the TSF; and
- For existing TSFs:
  - Reports on the geotechnical inspections and dam safety reviews;
  - Reports by the Engineer of Record (EOR) and any other Peer Reviewers;
  - Groundwater monitoring data to assess the extent, if any, of leakage that occurred from the facility; and
  - Information on any progressive reclamation performed.

If the TSF contains tailings with sulphide or other reactive minerals that have the potential to cause water quality impacts, other than suspended sediment issues, then the following additional information should also be assembled:

- Predictions and measurement of pore water, pond water and seepage quality from the active TSF;
- Acid base accounting, based on laboratory testing; and
- Humidity cell and/or field scale barrel testing.

This testing and information should provide data on both the quality and quantity of water that infiltrates through the waste and the quality of runoff that passes over the waste.

As part of the status assessment, the long-term performance of the embankment construction materials and the performance of any internal drains should also be assessed. Embankment construction materials subject to accelerated weathering and degradation could result in reduced strength over the long-term, potentially requiring reinforcement of the embankment, such as a downstream buttress fill. Oxidation of iron or chemical reactions by other constituents in embankment seepage may cause blockages of key drain systems in the embankment, which are intended to prevent the build-up of water pressures that could cause embankment failures. While this may not be expected during the operations phase, these issues may have to be addressed post-closure and during reclamation, by installing additional drains and/or constructing a buttress below the toe of the embankment to increase its stability under higher water pressures in the downstream shell.

In some instances, the foundation materials have the potential to impart dissolved salts or metals to groundwater under the embankment should the groundwater table rise due to seepage from the TSF. Where this occurs (e.g. TSFs constructed on desert salt flats), the water quality impacts of these formations should be assessed using testing of foundation samples during mine planning, as well as by groundwater and seepage monitoring during operations.

4.1.5 Risk assessment

A formal risk assessment of the closure and reclamation plan (or completed closure and reclamation) for the TSF should be completed as necessary when the closure and reclamation is first prepared and, as necessary, each time it is updated. This assessment should identify potential failure modes and consequences. Examples of where an updated risk assessment is required include where the embankment height exceeds the original design, where habitations have moved closer to the embankment and where the tailings properties are different to those originally anticipated, among others.

A closure and reclamation dam breach assessment should be considered both to determine the closure consequence classification and as input to the Emergency Response Plan for the TSF. Dam breach assessments, including flood extent (inundation) maps, should be conducted for all TSFs that will store water or contain liquefiable tailings in the long-term.

The following steps should be followed in a dam breach assessment:

- Select critical breach location(s); location(s) should have the highest potential for downstream impacts;
- Estimate the volume of tailings and water that will be released (Note: unlike water dams where a breach may result in 100% of the storage volume being released, tailings storage facilities will retain some solids due to the viscous nature of tailings);
- Determine breach parameters (e.g. geometry, rate of expansion, failure mode) and assign a predicted hydrograph;
- Route the flood downstream (1D or 2D model);
- Prepare inundation maps, including flood inundation extents, arrival times, depths, velocities and areas and infrastructure at risk; and

- Develop appropriate emergency preparedness and response plans.

4.1.6 Alternatives analyses

During the initial mine closure and reclamation planning process, a wide range of closure alternatives should be considered and screened-down to a shortlist of more viable alternatives. These alternatives should then be subjected to a more detailed comparative analyses, followed by selection of a preferred alternative.

The initial closure alternatives that should be considered typically include:

- In-place closure options, such as:
  - A drained-down facility with a cap and surface water diversions around the TSF. Different cover types can be considered including soil, vegetated soil, rock and gravel, store and release to reduce infiltration, and layered impermeable to eliminate infiltration;
  - A "wet" facility containing a water cover over the tailings and spillway, often considered for reactive tailings;
- Relocation options, such as:
  - Relocation of some or all the tailings into a mined-out pit or pits;
  - Relocation of all or some of the tailings into a new facility; this is usually not a viable candidate during initial planning but may have to be considered where an operating TSF fails and is not readily repairable;
- Filtered and slurry tailings options, which are typically considered during the initial planning stages, in accordance with the principle of early and integrated mine closure and reclamation planning closure. Closure of a filtered tailings pile should also consider different cover types
- Re-use of some or all of the tailings.

Later updates of the mine closure and reclamation plan would not usually require alternatives to be identified and analysed unless the previously selected plan is determined to be no longer feasible. This could, for example, include where physical or chemical characteristics of the tailings are significantly different from those originally predicted or mine plan changes require a significantly smaller or larger TSF. If a previously selected plan is determined to be no longer feasible, a limited number of alternatives should be considered in conjunction with updating the mine closure and reclamation plan.

4.1.7 Plan

The TSF closure and reclamation plan should generally include the following:

- General description of the TSF, deposition plans and history (where available), construction techniques used and operational processes;
- Description of the general status of the structure and its contained tailings as described above;
- Current landform and its relationship to the final storage geometry, as well as to the closure and reclamation design;
- Current survey plan of the facility (showing past and future staged earthworks);
- Condition of embankment used to contain the tailings, including an assessment of the impacts on stability of long-term weathering of the fill materials, as well as the performance of any drains needed to limit water pressures in the embankment;
- Overall long-term water balance of the facility;

- General water management plans including, as necessary, seepage collection and management, surface water management, the design of treatments to manage seepage and to dispose of any water treatment residuals;
- Long-term flood management strategies, as well as the strategy for containment or deposition of rainfall from the design flood event;
- Sources and properties of materials to be used as part of the decommissioning, closure and reclamation cover, and rehabilitation process;
- Proposed surface drainage works, including civil engineering design, construction and ongoing maintenance needs;
- Consideration and risk management of extreme events (e.g., drought, flood, fire, earthquake) during post-closure and reclamation;
- Overall closure and reclamation strategy for the TSF landform, addressing factors such as retention or drainage of incident rainfall, cover types required, and revegetation of covered or uncovered tailings;
- Surface treatment to minimize erosion (via rock cover and/or vegetation), sustain vegetation and support proposed rehabilitation design and stabilization works; and monitoring and audit requirements for the implementation, post-closure and reclamation phase

4.2 Water storage facilities

4.2.1 General

Water storage facilities can either be decommissioned on closure or retained over the long-term to provide for future water supplies, recreation or aquatic ecosystems – or a combination of these. The structures retaining water are typically engineered dams that rely on sound foundations and internal drainage systems to remain stable; if retained, these structures require a sophisticated long-term care program including professional engineering oversight monitoring, inspections, and maintenance programs. They also can represent risks at a closed mine site and a catastrophic failure of the containment dam can lead to loss of human life and environmental damage.

It is also important to note that the design criteria, such as the geotechnical criteria for confirming dam stability (e.g. the design earthquake) and the hydrological criteria (inflow design flood volumes and peaks flows) at a water storage embankment may need to be augmented at closure. This is because the closure period is typically much longer than the operating period and more stringent design criteria with lower frequencies of occurrence are needed to reduce the annual probabilities of failure to a reasonable value for the long-term closure period. This may require the installation of additional engineering measures, such as dam support buttresses and larger spillways.

4.2.2 Objectives

Specific long-term objectives for water storage facilities are determined by the mine closure and reclamation objectives and can include:

- The water structure should remain stable in the long-term;
- The long-term water quality regime should be consistent with the mine closure and reclamation objectives;
- Sediment accumulation over the long-term should not impair the future intended use or safety and security of the facility;
- Long-term maintenance requirements should be minimized; and
- Suitable design criteria should be selected to provide for an acceptably low risk over the long-term.

4.2.3 Approach

The following list and subsequent Clauses describe what actions should be undertaken for the preparation of mine closure and reclamation plans and designs for a water storage facility:

- Assessment of the status and condition of the storage facility;
- Risk assessment of the facility;
- Closure and reclamation alternatives analyses; and
- Closure and reclamation plan.

4.2.4 Status assessment

The status and condition of the water storage facility should be known in order to complete an effective closure and reclamation design. During the mine planning phases, the storage facility does not exist, and its initial design can serve as a basis for the closure and reclamation design. During operations and prior to the implementation of closure and reclamation, the condition and status of the storage facility should be determined.

Information required to determine the facility condition and status includes the following:

- Facility site geology and hydrogeology;
- Design drawings and specifications, or "as-built" details, drawings and construction QA/QC results;
- Predicted or measured water quality in the facility;
- Predicted or actual water balance of the facility; and
- For existing storage facility embankments:
    - Reports on the geotechnical inspections and dam safety reviews;
    - Reports by the EOR and any other Peer Reviewers; and
    - Groundwater monitoring data to assess the extent, if any, of leakage that occurred from the facility.

If the water storage facility is predicted to, or has already experienced significant sediment accumulation, the following additional information should be collected to determine facility condition and status:

- Catchment conditions and projected long-term sediment yields; and
- Estimates of the facility's sediment trap efficiency and projections of long-term sediment accumulation, in addition to the corresponding reduction in effective water storage.

The long-term performance of the embankment construction materials and the performance of any internal drains should be assessed. Embankment construction materials subjected to premature weathering and degradation may result in reduced strength over the long-term, and potentially require reinforcement of the embankment (e.g. downstream buttress fill).

4.2.5 Risk assessment

A formal risk assessment of the mine closure and reclamation plan (or completed closure and reclamation) for the water storage facility should be completed as necessary, when the mine closure and reclamation is first prepared and each time it is updated. This assessment should identify potential failure modes and consequences. Examples of where an updated risk assessment is required include where the embankment height exceeds the original design or where habitations have moved closer to the embankment, among others.

