INTERNATIONAL STANDARD

ISO 21795-2

First edition
2021-10

Mine closure and reclamation planning —

Part 2: Guidance

Planification de la fermeture et de la restauration des mines —

Partie 2: Recommandations

Reference number
ISO 21795-2:2021(E)

Contents

Page

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(see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 82, *Mining*, Subcommittee SC 7, *Mine closure and reclamation management*.

A list of all parts in the ISO 21785 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document 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. ISO 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, communities, indigenous peoples, and financial stakeholders, amongst others.

Mine planning, design and operations must be fully integrated with the closure and reclamation process. 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 mine closure and reclamation planning activities for new and operating mines. Recommendations are provided on:

— closure and reclamation of a mine site;

— land reclamation and water management;

— stakeholder engagement;

— decision and analysis tools.

The following aspects of closure and reclamation are not addressed in this document:

— infrastructure such as rail lines, ports, off-site ore loaders, power stations, etc. that are associated with the mine operation, but which are not located at the mine site;

— detailed survey, testing or monitoring methods, detailed engineering procedures, detailed product requirements, or detailed construction and operational procedures; occupational health and safety management related to closure and reclamation, construction and exploration activities;

— relinquishment of a closed and reclaimed mine site, or portions thereof, to a party (governmental or private entity) not related to the mine operator;

— specific requirements for dealing with the radiological aspects of mine closure and reclamation, such as those that occur at uranium mining and processing facilities and other mines at which naturally occurring radioactive materials are present; however, the other aspects associated with closure and reclamation of these mines are included in this document; and

— 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.

ISO 20305, *Mine closure and reclamation — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 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 https://www.electropedia.org/

4 Closure and reclamation of a mine site

4.1 General

During the mine closure and reclamation planning and design process, a significant amount of knowledge from a range of internal and external sources, including government agencies, consultants, indigenous peoples and other landowners/users, downstream water users, as well as from field investigations, laboratory testing and field trials and research, is collected. This data collection process should be initiated early in the mine life cycle in order to produce a more comprehensive and precise database. The collected data should be summarized in reports, maps and electronic information in a form that can be used in geographical information systems (GIS) and, if necessary, be provided to stakeholders. Digitizing and geo-referencing old maps found in various archives should be avoided or undertaken with care, since their quality can be quite poor.

4.2 Tailings storage facilities

4.2.1 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.

The design criteria, such as the geotechnical criteria for confirming dam stability (e.g. the design earthquake) and the hydrological criteria (e.g. inflow design flood volumes and peaks flows) at a TSF can require 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 can require the installation of additional engineering measures, such as dam support buttresses and larger spillways.

Tailings can also be filtered to remove excess moisture, and the resultant tailings waste can be stored in a compacted pile, referred to as a dry stack. Dry stack tailings are typically unsaturated and have sufficient strength to be placed in compacted layers without a containment dam. In some cases, they can contain enough moisture to render them liquefiable, which requires some form of containment. Dry stacks typically require less intensive post-closure and reclamation care and professional oversight, monitoring and inspections than tailings dams. Since dry stacks are susceptible to water and wind erosion, they can require long-term maintenance.

In some regulatory jurisdictions, TSFs that contain water or liquefiable tailings are classified as dams and require sophisticated long-term care programs, including professional engineering oversight monitoring, inspections and maintenance as discussed above. Dry stacks on the other hand, can be classified as waste piles, and similar to waste rock dumps discussed in 4.4, require less care and maintenance than a TSF.

Subclauses 4.2.2 to 4.2.7 apply to TSFs. Generally, these are also applicable to dry stacks. Were these requirements differ from those for dry stacks, these differences are noted. Furthermore, many of the approaches described in 4.5, for heap leach facilities, also apply to dry stacks.

4.2.2 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.

4.2.3 Approach

Subclauses 4.2.4 to 4.2.7 describe the following actions that 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 (4.2.4);

— risk assessment of the TSF (4.2.5);

— closure and reclamation alternatives analyses (4.2.6); and

— closure and reclamation plan (4.2.7).

4.2.4 Status and condition 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 may not exist, in which case its design can serve as a basis for closure and reclamation planning and 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:

— TSF site climate, geology, hydrology and hydrogeology;

— design drawings and specifications or "as-built" details, drawings and construction quality assurance/quality control (QA/QC) results;

— predicted and actual physical and geochemical characteristics of the tailings, where:

  — physical characteristics include the particle shape (e.g. granular or fibrous), particle size distribution and the moisture content, and

  — chemical characteristics include the mineral types, the presence of minerals that react with air and water to release soluble contaminants, and residual reagents, amongst potentially others factors;

— 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,

  — surface water and 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 can 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 can cause blockages of key drain systems in the embankment, which are intended to prevent the build-up of water pressures that can cause embankment failures. While this is not expected during the operations phase, these issues should be addressed during closure and 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, e.g. where the groundwater table rises due to seepage from the TSF, the foundation materials have the potential to impart dissolved salts or metals to groundwater under the embankment. 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.

These requirements are generally applicable to a dry stack. In the case of a dry stack, the requirements stated above for the tailings generally apply to the stack. Furthermore, dry stacks are closed as piles and not as water retaining structures.

4.2.5 Risk assessment

A formal risk assessment of the mine closure and reclamation plan (or completed closure and reclamation) for the TSF should be completed when the closure and reclamation is first prepared and, as necessary, each time it is updated, and for the completed mine closure and reclamation. 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. Appropriate international guidelines are available for conducting dam breach assessments. Based on the results of these assessments, an appropriate emergency and preparedness and response plan should be prepared and implemented.

4.2.6 Closure and reclamation 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 analysis, followed by the selection of a preferred alternative.

The initial closure alternatives that should be considered include:

— in-place closure options, such as:

  — a drained-down facility with a cover 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, and

  - 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 tailings into a mined-out pit or pits, and
  - relocation of all or some of the tailings into a new facility; this is usually not a viable candidate during initial planning but should 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.

Later updates of the mine closure and reclamation plan usually should not require the identification and analysis of alternatives, unless the previously selected plan is determined to be no longer feasible. This can include, for example, where physical or chemical characteristics of the tailings are significantly different from those originally predicted, or where 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.

For dry stacks the list of closure alternatives is shorter and typically includes:

- in-place closure options, such as:
  - closure based on the as-place topography,
  - regarding to flatten slopes, and
  - different cover types;

- relocation options, such as:
  - relocation of some or all the tailings into a mined-out pit or pits, and
  - re-use of some or all of the tailings.

4.2.7 Closure and reclamation 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;
- 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;
- considerations of climate change and the necessary design adjustments;
- 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 that should 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 closure and post-closure.

4.3 Water storage facilities

4.3.1 General

Water storage facilities (WSFs) can either be decommissioned on closure or retained over the long-term to provide for future water supplies, water treatment systems, 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.

The design criteria, such as the geotechnical criteria for confirming dam stability (e.g. the design earthquake) and the hydrological criteria (e.g. inflow design flood volumes and peaks flows) at a water storage embankment can require 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 can require the installation of additional engineering measures, such as dam support buttresses and larger spillways.

4.3.2 Objectives

Specific long-term objectives for WSFs are determined by the mine closure and reclamation objectives, and include:

— the water retaining structure should remain stable in the long-term;

— the long-term water quality regime should be consistent with the mine closure and reclamation objectives and relevant regulations;

— sediment accumulation over the long-term should not impair the future intended use or safety and security of the facility;

— appropriate flood design criteria and adequate provision for water storage during drought conditions should be considered if appropriate;

— 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.

4.3.3 Approach

Subclauses 4.3.4 to 4.3.7 list and describe the following actions that 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 (4.3.4);

— risk assessment of the facility (4.3.5);

— closure and reclamation alternatives analyses (4.3.6); and

— closure and reclamation plan (4.3.7).

4.3.4 Status and condition 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 may not exist, in which case its initial design can serve as a basis for the closure and reclamation planning and 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, but is not limited to, the following:

— facility site climate, geology, hydrology 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;

— for existing storage facility embankments:

  — reports on the geotechnical inspections and dam safety reviews,

  — reports by the EOR and any other peer reviewers, and

  — surface water (including seepage) 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 experience, 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 can result in a reduced strength over the long-term, and can require reinforcement of the embankment (e.g. downstream buttress fill).

4.3.5 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 when the mine 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

