Yukon

Guidelines for Mine Waste Management Facilities

February 2023

Acknowledgements and document history

This document is the result of a number of initiatives from 2015 through 2022. The work was completed with the support of many subject-matter experts from a variety of fields and backgrounds.

About this document

In 2016, an initial draft document underwent a peer review by subject-matter experts. The comments received were incorporated into a revised draft in 2017. This revised draft was issued for review and comment; opportunities for written and verbal input were provided, including a series of facilitated workshops. Comments were received from industry, environmental non-government organizations, Yukon First Nation governments, the Yukon Water Board, the Yukon Environmental and Socio-economic Assessment Board and Government of Yukon departments.

Yukon government received funding from Natural Resource Canada's Climate Change Adaptation Program in 2018. This funding was used to ensure climate-related influences and impacts to the design, operation, maintenance and closure of waste management facilities on quartz mine sites were adequately addressed in the document.

The final document, issued in February 2023, incorporates all of the information and feedback received from the previous reviews and processes.

This is a living document and will be reviewed and updated to accommodate changes in management approaches and legislation. Please send any comments, questions, or feedback to the Major Mines Licensing Unit at emr-qml@yukon.ca.

Acknowledgements

The completion of this document would not have been possible without the significant contributions from the individuals and organizations listed below.

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Acronyms

AEP	Annual exceedance probability
EDGM	Earthquake design ground motion
EDF	Environmental design flood
EOR	Engineer of record
IDF	Inflow design flood
IRB	Independent review board
HLF	Heap leach facility
ML	Metal leaching
MRMF	Mine rock management facility
MWMF	Mine waste management facility
NAG	Non-acid generating
PAG	Potentially acid generating
QML	Quartz mining license
TMF	Tailings management facility
WUL	Water use licence
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board

Glossary of terms

Active closure stage	The period of time following the completion of mining when the mine operator conducts the decommissioning of mine facilities, completes the physical closure activities and ensures effectiveness of closure measures through follow-up monitoring and maintenance.
Active management	Activities that require planned or regular human intervention, excluding monitoring activities, to ensure effectiveness.
Adaptive management	The process of planning a response to circumstances or events that may not be fully predictable or expected. Adaptive management identifies, in advance, actions that must be taken to gather information and respond appropriately in the event of an unanticipated or unpredictable circumstance.
Care and maintenance	The processes and activities undertaken at an inactive mine site where: (1) there is potential to recommence operations at a later date or (2) where initiation of permanent closure of the mine site has not yet commenced. During a period of care and maintenance, the mine site is managed to ensure it remains in a safe and stable condition and the environment is protected.
Closure	The period after operations cease, during which decommissioning and reclamation occur. The goal is a post-closure period with physically and chemically stable facilities that require limited maintenance and monitoring and meet desired land use objectives.
Consequences of failure	Negative impacts to the natural or built environment resulting from the failure of a mine waste facility or its appurtenances, structures or equipment. Consequences of failure are generally considered in terms of the health and safety, social,

	environmental, cultural, and economic impact caused by the effects of a failure occurring.
Construction drawings	Design drawings that provide a graphical representation of the proposed work activity that needs to be done in the construction of a project, and has been approved by the owner, engineer of record and regulators.
Contact water	Water that is in contact with or originates from mine waste materials or lands influenced by mining or mine construction processes.
Dam[1]	A barrier constructed for the retention of water, fluid waste, or tailings, provided the barrier is capable of impounding at least 10,000 m^3 of such materials, and is at least 3 m high, as measured vertically from the downstream toe at the natural valley bed up to the crest elevation.
Decommissioning	The process that begins near or at the cessation of mineral production and ends with the removal of all unwanted infrastructure and services.
Design engineer	A professional engineer responsible for the design and preparation of specifications and construction drawings for a construction project
Professional engineer	A professional engineer (P.Eng.) is an individual as defined in, and licensed under, the *Engineering Profession Act*, R.S.Y. 2002, c.75 with experience in design, operation, or closure of mine waste management facilities.
Engineer of record (EOR)	A qualified professional engineer registered in the Yukon, with experience in the design, construction, operation and closure of mine waste facilities in cold climates, who has explicit

[1] As defined in the Yukon Waters Act

	professional responsibility for the safety and performance of the mine waste facility. The EOR may not necessarily be the design engineer of the facility.
Facility class	A three-tiered system used in this document to identify classes of mine waste management facilities ranging from relatively small, simple, low-risk structures (Class I) to larger, more complex, higher-risk structures (Classes II and III).
Ice-rich permafrost	Perennially frozen soil or rock that contains ice in excess of that required to fill pore spaces. When ice-rich permafrost thaws, water in excess of that required to fill the pore space is released and the material typically experiences significant thaw settlement or loss of strength, or both, upon thawing.
Independent review	A systematic evaluation of all technical, management and governance aspects of a mine waste management facility across the life cycle conducted by competent, objective, third-party reviewers.
Independent review board (IRB)	A group comprised of peer reviewers appointed to provide independent, expert oversight, opinion, and advice to a proponent on the design, construction, operational management and closure of a MWMF.
Interested parties	Parties typically involved in the effects assessment, permitting, construction, operational and closure approvals for a mine. These include federal, territorial, and First Nation government agencies, and may also include non-governmental organizations, local communities and other parties that are affected by, or have an interest, in the mine.
Mine waste	The remaining geologic material, mineral processing residues and water treatment residues resulting from mining operations.

Mine waste management facility	Facilities and structures on mine sites constructed for the purposes of storing mine waste.
Non-contact water	Water that is not in contact with, or does not originate from, lands influenced by mining or construction processes.
Owner	The proprietor of the facility, including agents or other persons acting on behalf of the owner.
Passive water management	Passive systems include those for which no human or limited intervention is required and include dispersion into large water bodies, wetlands, large oxidation/filtration ponds, etc.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below zero degrees Celsius for at least two consecutive years.
Proponent	The person or body that is licensed for, or proposes to undertake, a quartz mining project, and is responsible for the submission of applications, plans and reports in relation to the project.
Qualified environmental professional (QEP)	An applied scientist or technologist who can conduct assessments as individuals or together with other qualified environmental professionals. A QEP must have an area of expertise that is recognized in the assessment methods as one that is acceptable for the purpose of providing all or part of an assessment report for the particular development proposal that is being assessed.
Responsible person (RP)	A person who has clearly defined, delegated responsibility for mine waste management and appropriate qualifications.
Reclamation	The reconditioning of disturbed land to a stable and socially acceptable future land use.

Regulator	A government department, office or independent agency entrusted by law with the responsibility for the permitting of a mine waste facility or enforcing compliance with the conditions of a regulatory permit issued for a mine waste facility.
Thaw-stable permafrost	Perennially frozen soil or rock that does not typically experience significant thaw settlement or loss of strength upon thawing.
Yukon closure guide	A guide that describes the expectations of closure plans and financial security estimates for quartz mines in Yukon developed by Yukon government and Yukon Water Board entitled *Reclamation and Closure Planning for Quartz Mining Projects*, dated August 2013, or subsequent revisions.
Yukon closure policy	A policy describing the requirements for reclamation and closure of quartz mines in Yukon entitled *Yukon Mine Site Reclamation and Closure Policy*, dated January 2006 or subsequent revisions.
Yukon plan guide	A guide that describes the expectations of environmental and operational plans for quartz mines in Yukon developed by the Yukon government and Yukon Water Board entitled *Plan Requirement Guidance for Quartz Mining Projects*, dated August 2013 or subsequent revisions.

Executive summary

This document provides guidance to quartz mining applicants and licensees on the expectations and requirements with respect to planning, design, construction, operation and closure of quartz mining mine waste management facilities in Yukon. It describes the Government of Yukon's expectations of proponents during the assessment and regulatory phases of a project and provides the minimum expected management practices during development, operation and closure of quartz mining projects.

This document uses a three-tiered facility class system to differentiate between requirements for relatively simple, low risk mine waste facilities (Class I) and larger, more complex, higher risk facilities (Classes II and III).

1. Introduction

Quartz mining projects are undertaken to extract valuable mineral commodities from geologic deposits. An unavoidable byproduct of the extraction process is the creation of significant volumes of mine waste such as disturbed geological materials and mineral processing and water treatment residuals. The types of waste materials created may include excavated overburden and waste rock, tailings, spent heap leach ore, contaminated process water and water treatment sludge or brine.

Consistent with modern practices and societal expectations, these mine waste materials must be stored in designed waste management facilities. Such facilities must be planned, developed and operated so that the waste does not result in unaccepted physical or chemical effects on the human and natural environments. Facilities must ultimately be closed so that the stored wastes are physically and chemically stable in the long term and meet accepted post-mining land use objectives. These objectives must be achieved with minimal ongoing human intervention.

1.1. Document purpose

These guidelines have been developed to assist proponents in achieving the above goals, as they are understood in the context of the Yukon assessment and regulatory system. These guidelines are written specifically for use by parties experienced in the planning, development, operation and closure of mine waste management facilities. As such, the guidelines are not intended to be a comprehensive explanation of the means to bring mine waste management facilities into operation and close them. Proponents are expected to use only qualified and experienced personnel and consultants familiar with the planning, development, operation and closure of mine waste facilities. The intent of this document is to provide guidelines that these personnel and consultants can use in respect to specific or unique requirements associated with mine waste management in Yukon.

As such, the guidelines describe the minimum expected requirements for the planning, development, operation and closure of mine waste management facilities in Yukon.

When developing assessment and regulatory applications for mine waste management facilities, proponents are encouraged to read these guidelines in full to be informed of the expectations for such submissions.

Notwithstanding the contents of these guidelines, assessment and regulatory agencies will evaluate mining proposals on a case-by-case basis with consideration of relevant site-specific information and evolving states of practice.

This guideline has strived to incorporate current standards, technologies and best practices applied in other jurisdictions across Canada and to take into consideration the recommendations of recent technical reviews. A complete list of reference material used in the development of this guideline can be found in Chapter 7.

1.2. Guideline structure

In addition to this introductory chapter, these guidelines include Chapter 2, which describes general information for mine waste management facilities (MWMFs), Chapter 3, which describes planning and management practices, and facility-specific chapters 4, 5, and 6, which describe tailings management facilities (TMFs), heap leach facilities (HLFs) and associated solution ponds, and mine rock management facilities (MRMFs), respectively.

Each of the facility-specific chapters describes the:

- requirements for determining the facility classification;
- steps and methods for conducting alternative analyses (e.g. site selection and waste management method selection);
- specific design requirements for the construction of a facility;
- requirements for the operation and monitoring of a facility;
- objectives and criteria for the closure of a facility; and
- post-closure monitoring and maintenance requirements.

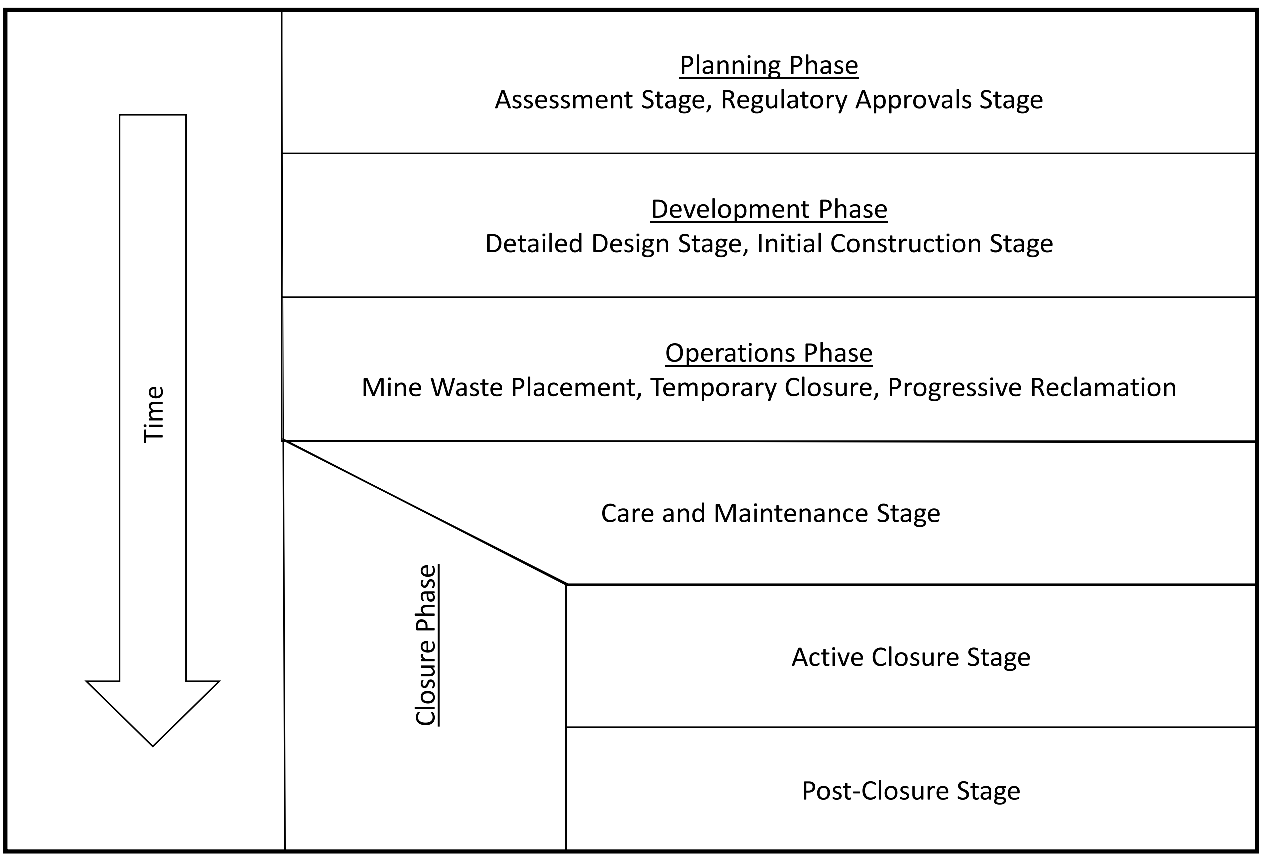
The chapters in this guide are supported by seven appendices that describe a series of general planning or management practices that apply to all types of these facilities:

- Baseline data collection describes the minimum requirements for the collection of environmental baseline data that must be carried out to support assessment and regulatory applications.
- Site characterization describes the site characterization that must be carried out to support assessment and regulatory applications.
- Description of design levels describes the expected level of engineering design required to support the planning, development, operation or closure of a MWMF, and the information and studies that must be submitted to support that design for each stage of the assessment and regulatory processes.
- Options assessment describes the process of evaluating potential options that must be undertaken when planning a MWMF.
- Risk assessment approach describes the approach to be used when conducting a risk assessment as part of planning, developing, operating or closing a MWMF.
- Construction plans for mine waste management facilities describes the information that must be contained in construction plans for MWMFs.
- Environmental monitoring requirements describes the expected frequency and breadth of environmental monitoring during the development, operations and closure phases of the MWMF.

2. General information and required practices

This chapter briefly outlines general information relevant to MWMFs; this begins by defining the phases and stages of a mine waste facility that are to be used in submissions supporting such facilities. These phases and stages are illustrated in Figure 2-1. The chapter also describes the level of engineering design required to support facilities at various points in time, and a facility classification scheme that is to be applied.

Figure 2-1: Phases and stages for mine waste facilities



2.1. Phases and stages covered by these guidelines

All MWMFs progress through various life phases, beginning with planning and ending with closure. Such phases may also include distinct intermediate stages. For the purposes of assessment and regulatory submissions, the following nomenclature is to be applied to describe the life phases and stages of MWMFs.

2.1.1. Planning phase

This phase includes the planning activities that result in the selection of a proposed MWMF by the proponent and the approval for development of that facility by regulatory authorities.

The planning phase is when the waste storage location and management approach is chosen by the proponent and supported by engineering analyses, designs, management plans, a closure plan and performance predictions. These analyses, designs, plans and predictions are submitted for assessment; regulatory approvals are required to allow for development of the facility. The planning phase has two distinct stages – the assessment stage and the regulatory approvals stage:

- **Assessment stage** – In this stage, the proponent seeks to complete the environmental and socio-economic assessment of the facility (generally in association with such an assessment for the entire mining project). It is expected that a positive economic feasibility study for the overall project, demonstrating the project is economically viable, has been completed by the proponent, and that this study includes the specific mine waste facility. During the assessment stage, it is expected that considerable efforts will be required to characterize the facility site and describe the MWMF's design, operations, and closure. Proponents are expected to define and defend design and performance criteria and predict the performance and effects of the facility.
- **Regulatory approvals stage** – In this stage, the proponent seeks to obtain regulatory approvals. It is normally expected that designs and management plans will be advanced and refined from those prepared during the assessment stage. It is also expected that updated results from baseline

monitoring programs for key dynamic type parameters (water quality, climate, hydrology, etc.) will be incorporated into supporting documents. Often specific additional planning studies, such as further site geotechnical characterization programs and analytical exercises (e.g. advanced water balance and water quality modelling exercises) are required to be completed in this stage. Overall, it is expected that the level of confidence in the predicted performance of the facility will be increased through this stage

2.1.2. Development phase

The development phase is when detailed designs and project execution plans for the facility are finalized and submitted to regulators for approval, management plans are updated or created as required by conditions received in the regulatory approvals and the facility is constructed such that it can begin to receive mine waste. Generally, it is expected that the development phase will include a detailed design stage and an initial construction stage:

- **Detailed design stage** – during this stage, detailed construction drawings (Issued for construction level drawings), specifications including quality control and quality assurance requirements and associated reports are prepared and the project execution plan (construction plan and schedule) for the facility is finalized.
- **Initial construction stage** – during this stage, the initial construction of the facility takes place so that the facility is prepared to receive the designated mine waste. Monitoring of both the quality and the effects of construction are expected to be performed in this stage.

For facilities designed to have staged construction, the development phase applies only to the construction of the first stage; subsequent stages occur in the operations phase.

2.1.3. Operations phase

This phase begins when mine wastes are first deposited in the facility and ends when no further waste is planned to be deposited. The operations phase may include periods where there is a temporary, planned or unplanned, cessation of waste placement.

The operations phase may include distinct stages when the facility's capacity to store waste materials is limited to some volume less than the ultimate planned storage capacity and further construction occurs to expand the capacity of the facility. If a staged approach to operation of the facility was part of the original planning there will be a concurrent overlap of development activities and operations for the facility.

It is common for mine plans to expand after the initial approval of a project and this may lead to previously unplanned expansion of mine waste management facilities. In such cases, the unplanned expansion would be required to re-enter the planning and development phases concurrent with the operations phase of the original approved facility.

Construction activities associated with progressive reclamation of the facility may also occur during the operations phase. Conducting such activities does not change the life phase of the facility from operations to closure.

It is normally expected that advancement of the closure plan for the facility will occur throughout operations as operational monitoring data is acquired and reclamation research is completed using actual facility waste products.

2.1.4. Closure phase

For TMFs and MRMFs, this phase begins when placement of additional mine waste in the facility is no longer planned and continues for as long as the facility is present. For HLFs, closure starts when no more ore is planned to be added to the heap and no active leaching agents are added to any recirculated heap fluids. In all cases, once closure is initiated it continues for as long as the facility remains. The closure phase is normally expected to include three distinct stages:

- **Care and maintenance stage** – at this stage of the closure process, the facility is maintained to ensure physical and chemical integrity, but substantial modifications are not yet undertaken to prepare the facility for closure and to achieve the ultimate land use goals. During this stage modifications to the closure management plans and development of implementation plans is expected to occur. This stage may be relatively brief or absent for facilities that have well-executed mine plans and well-defined closure plans.

- **Active closure stage** – During this stage, the reclamation and closure plan for the facility is implemented including any physical works, component upgrades and development of temporary active water treatment facilities or permanent passive water treatment facilities. Depending on the need for treatment of contact water from the facility, the active closure stage may be relatively short (a few years to complete physical modifications) or several decades in duration. It is expected that active management and robust monitoring of the performance of closure measures will be an integral part of the active closure stage. Where a permanent means of passively treating contact water from a closed facility is planned, the active closure phase will require significant effort to prove the performance of the passive treatment approach.
- **Post-closure stage** – This stage follows the active closure stage and entails the facility being in a long term, stable, quasi-steady state with acceptable closure performance and land use outcomes. During this stage, the level of maintenance and surveillance of the facility is expected to gradually reduce on an approved schedule. This stage cannot include active management of the facility unless it has been determined that passive management is not and will not be successful. While it is expected that the level of monitoring and maintenance of the facility will reduce over time, it is not expected that a complete cessation of monitoring and maintenance will necessarily be achieved.

2.2. Facility classification system

In these guidelines, it is recognized that MWMFs create an inherent hazard that must be appropriately managed to protect the human and natural environments. It is also recognized that the consequence of failure of mine waste facilities is strongly correlated to the hazard level represented by the facility. Given this, it is the basic premise of these guidelines that as the hazard level and associated consequences of failure represented by the facility increase there is a need to correspondingly increase the rigor applied to the design and management of the facility.

As summarized in Table 2-1, these guidelines define three classes that a given facility may fall into. For each class Table 2-1 presents a narrative description of the general nature of facilities in a given class and of the potential effects arising from a failure of each class of facility. The descriptions are intended to be indicative as opposed to definitive and should be read as such. To put the facility classes into perspective, Table 2-1 also lists the equivalent dam classifications used by the Canadian Dam Association (CDA, 2016) for tailings embankments and water dams.

For clarity, this guideline defines facility classifications not only for dams, but also for other types of mine waste facilities including filtered tailings facilities (dry stacks), heap leach pads and waste rock dumps. Chapters 4, 5, and 6 provide details on how to apply the classification system to TMFs, HLFs, and MRMFs, respectively.

Under these guidelines, facilities that fall into different classes must follow and implement different minimum design criteria, and different minimum planning and management practices. The choice of three classes for this system arises from there being practical limits and diminishing benefits to how finely the types of design criteria and management practices can be divided. It is also recognized that boundaries zones between classes are generally problematic and should be minimized.

Unlike the approach of the Canadian Dam Association that looks only at consequences of failure to derive classifications, this classification system is based on consideration of intrinsic characteristics of facilities that can be viewed as representing or contributing to the hazard associated with that facility. For example, the volume and reactivity of the stored mine wastes are characteristics that are linked to the potential hazard represented by the facility. This approach recognizes the greater challenges, complexities and uncertainty that exists in predicting the potential consequences of failure for MWMFs as compared to conventional water storage dams.

Table 2-1 Facility classification

TABLE 2-1 FACILITY CLASSIFICATION		
CLASSIFICATION	DESCRIPTION[2]	CDA DAM HAZARD CLASSIFICATION
Class I	The facility is of a modest size and contains relatively benign and stable materials. It is not likely to have physical or chemical effects beyond a small local area. A failure would not pose a significant threat to human health and safety, and would be repairable and reversible using the owner's locally available resources.	Low
Class II	The facility may be large but not of uncommon size compared to existing facilities with long and acceptable operational records. The stored materials are predominately of benign or of minor chemical risk or are secured by multiple containment barriers. The facility may have the potential for significant physical or chemical effects beyond the limits of the site, but these can be addressed by application of standard engineering practices and proven mitigation measures that do not require long-term active management. A failure of the facility could pose a significant threat to people temporarily on the mine site, or it could create significant but temporary acute effects beyond the limits of the site that could require multiple years of planning and construction to address. A reasonably resourced owner would be able to manage the recovery with only oversight by government.	Significant & High
Class III	The facility may be pushing the state of the practice in terms of its size or design, or may contain chemically aggressive materials that could be released in association with a containment failure. Managing the potential effects associated with the facility requires one of more of: (1) application of specialized engineering practices or extrapolation of standard practices, (2) application of mitigation measures that have not been proven for the proposed purpose or that have significant uncertainty, or (3) long-term active management. A failure of the facility could pose a significant threat to people outside of the project site. The failure of the structure would create significant hardship and widespread effects well beyond the limits of the site. The environmental effects may not be fully reversible and could take generations to reach a new sustainable ecological state. The failure may lead to the need for permanent management and may exceed the ability of a reasonably resourced owner to address without significant government support.	Very High & Extreme

[2] The narrative description of the facility classes is meant to provide a rough, magnitude of order definition. It is not intended to account for all of the factors that are considered in reaching a formal classification for a given facility.

2.3. Design level

Progressive phases and stages of a MWMF will require supporting engineering designs that become more detailed as the facility or its component progresses from an initial concept to its fully built realization. Within the Yukon assessment and regulatory processes, there are normally six design milestones associated with a facility or a component of a facility.

These milestones are the designs required to support:

- the screening of potentially suitable design options and locations;
- the selection of a preferred alternative from a set of potential locations and technologies;
- establishing the feasibility of the selected alternative and assessing its effects;
- the issuing of regulatory permits;
- the initiation of construction of the facility or its component; and
- the confirmation of the actually constructed facility or its component inclusive of any field modifications that were applied during its construction.[3]

Associated with these milestones are well-recognized and accepted design levels that are common in civil engineering practice. While the design levels are common, there is within different engineering disciplines and different engineering organizations a wide range of terminology and conflicting terminology to describe the design continuum that starts with a concept for a facility and ends with its physical production. So, for the purposes of assessment and regulatory submissions in Yukon, the terminology presented in Table 2-2 must be used.

[3] The confirmation design level (as-built design) is in common practice not considered a design level per se, but for the purposes of this guideline it has been identified as such.

Table 2-2 Design terminology

Table 2-2 Design Terminology	
Design Stages Adopted in This Guidance Document	**Design Stages Used by APEGBC**
Conceptual design	Scoping level design
Pre-feasibility design	Pre-feasibility design
Feasibility design	Feasibility
Preliminary design	
Detailed design (Issued for construction)	Detailed design
As-built design	N/A

Details on the function and description of these six design levels are presented in Table 2-3 and in greater detail in Appendix C.

Table 2-3 *Design level descriptions*

Table 2-3 Design Level Descriptions		
Design Level	**Function/Description**	**Milestone/Use**
Conceptual	Concepts are based on experience at similar facilities and available site-specific data including topographic, geologic, soils, permafrost, vegetation and other environmental mapping and information. As a minimum, a site reconnaissance should have been conducted and in some instances preliminary field data may be required to characterize critical unknown field conditions. The designs should reflect the volume estimates and footprints of the major facilities and include reasonably conservative provisions for adequate foundations and stable structures. Designs should not include any obvious technical fatal flaws.	To establish an initial inventory of potential sites and technologies that will be screened down for inclusion in an options analysis. Can also be used to develop preliminary classifications for the facilities based on the criteria established in Tables 4-1, 5-1, 6-1 of this document.
Pre-feasibility	Designs depict feasible concepts and dimensions without engineering or technical fatal flaws. Feasibility of the designs can be assessed based on a combination of more field data and laboratory testing for conceptual designs and reasonable assumptions backed by sound professional judgement. Engineering analyses must be performed for all major facilities including materials mass balances for construction, geochemical characterization of waste and construction materials, slope stability analyses, hydrology studies, water and chemical balance analyses and hydraulic designs. It must be possible to address uncertainties in the design by appropriate cost contingencies.	Generally performed on a short list of possible options and used to select the preferred option for a facility that will be included in the mine's development plan and which will be subject to environmental assessment. Information is also used to develop final classifications for the facilities based on the criteria established in Tables 4-1, 5-1, 6-1 of this document.
Feasibility	A selected design depicts feasible concepts and detailed plans without fatal flaws. Feasibility of the design must be demonstrated by collecting additional field data as necessary and undertake sufficient field and laboratory testing and more detailed engineering analyses of those listed under the pre-feasibility design level. Use of reasonable assumptions backed by sound professional judgement to fill in data gaps should be limited to the design of minor, non-critical elements. As a minimum, conceptual construction specifications should be included.	Required for obtaining regulatory approvals. This design is usually only prepared for the preferred option selected during the environmental assessment process.
Preliminary	Optimized designs are supported by additional field data and field and laboratory testing if needed, and analyses based on known ranges of input parameters to substantiate that the optimum design has been achieved and that construction and performance risks can be appropriately managed. More design details are provided for ancillary facilities such as spillways and ditches and any associated mechanical and electrical equipment. As a minimum, draft detailed construction specifications and operating and monitoring plans should be included.	May be required for obtaining regulatory approvals described above where more detailed information on designs of ancillary features and the mechanical and electrical equipment and the operations is required by regulators. May also be required by the mining company to reduce cost estimating uncertainty.
Detailed design (issued for construction)	The "issued for construction" design and supporting documents allow for construction and monitoring of construction quality. This primarily addresses full detailing of interactions between adjacent design elements and foundations, as well as structural, mechanical and electrical details. Must include final detailed construction drawings and specifications.	Required prior to construction of any facility for review and approval by the regulators.
As-built	To document the actual as-built configuration and placement quality of materials used in the completed construction. Accounts for any field modifications to the detailed design that occurred, records results of quality assurance and quality control activities, deviations from expected site conditions or construction materials and any other factors that could impact the performance of the facility.	Required when assessing the suitability of the facility to be commissioned for initial use and to guide any expansions or later stages as well as closure designs.

While conceptual, pre-feasibility and detailed designs are likely to be relatively uniform across facility classes, proponents should expect that acceptable levels of detail for feasibility and preliminary designs may vary substantially between the three facility classes.

The variance in the suitable feasibility and preliminary designs will be evident in the degree of effort required to:

- minimize geological uncertainty and uncertainty in respect to construction materials;
- confirm logistical constructability or limitations of such;
- anticipate and integrate operational and closure challenges, constraints and requirements for flexibility; and
- the rigour to be applied in engineering analyses.

Specifically, as the facility classification increases so does the need to de-risk the feasibility and preliminary designs. De-risking these designs is normally accomplished by increasing the level of confidence in the design through:

- more intense site characterization;
- more analytically or numerically rigorous engineering analyses;
- increasing use of probabilistic or stochastic inputs in supporting models;
- use of greater precaution in the selection of extreme environmental parameters;
- greater examination of effects of variation in the mine plan, the mass balance and the water balance; and
- formal integration of the design and operational teams, as well as engagement with communities of interest and independent reviewers.

Greater relative confidence in the ability to appropriately close the facility is also an expected de-risking task associated with increasing hazard classes.

Cross-discipline integration within the planning team can also help to de-risk the design because it provides a better opportunity for a comprehensive understanding of inter-related design and performance requirements. Similarly, better coordination between the design team and the operations team can also help to de-risk the design.

It can be beneficial, for example, to engage senior operating personnel during the feasibility design level to bring careful consideration of operational requirements. Finally, independent review processes can be incorporated at all stages of design as a method for understanding and minimizing risks.

3. Planning and management practices

This chapter briefly outlines the required planning and management practices associated with MWMFs in the Yukon. This includes a description of the requirements for collection of baseline information and management practices that are expected to be followed for each facility class. The management practices described in this chapter include options analysis, risk assessments, independent reviews, auditing requirements, and water treatment systems requirements.

3.1. Collection of baseline information

To meet the purposes of these guidelines, mine waste management facilities must be planned, developed, operated and closed based on the site-specific characteristics of the facility location, areas or regions that may be affected by the facility. Characterization of site locations and potentially affected areas will involve collection of relatively static and dynamic baseline information. For the dynamic characteristics of areas, a baseline monitoring program must be of sufficient length and frequency to develop an understanding of variability.

Baseline monitoring and observations for dynamic characteristics must be from a period of at least three consecutive years and must provide an understanding of the variability of the site, including temporal (e.g. inter-annual and seasonal) and spatial variability.

Appendices A and B provide details on the minimum information that must be collected, and analysis that must be performed to support the planning, development, operation and closure of mine waste management facilities described in this document.

3.2. Planning and management practices

Achieving or exceeding objectives for MWMFs relies on the development of resilient engineering designs followed by effective implementation of designs and careful operation of facilities. The planning, design, construction, operation and closure of the facility must be fully integrated and requires development and implementation of various planning and management practices that provide appropriate confidence in the success of the facility. Appendix C describes the level of design expected for the various phases of mine planning and how these phases tie into the assessment and regulatory processes.

MWMFs should include site selection studies and alternative analysis to determine the most suitable site for the facility and to confirm that best available technologies are being implemented. The facility will require classification to guide the minimum expectations for site investigations and engineering required. Facilities also require detailed information on the chemical and physical properties of the waste materials, detailed water balance and water quality studies to characterize water management requirements, and closure plans that provide for long-term physical and chemical stability.

Tables 3-1 through 3-5 describe requirements for several key management practices through each of the MWMF phases, including options assessment, risk assessment, independent review, MWMF audits and water treatment design. The need and rigour for various supporting practices may vary depending upon the classification of the facility.

All MWMFs must be designed and operated in accordance with the design-for-closure approach. Decisions made during planning, development and operations will both define and constrain options for reclamation and closure and may affect the achievability of mine closure objectives. Therefore, closure planning for MWMFs must be conducted in parallel with initial option selection, site selection and design, and considered throughout development and operation.

At all times through development, operation, and closure there must be a designated engineer of record (EOR). During development and operation phases, there must also be a responsible person (RP) for the MWMF.

The RP must be an employee of the owner who is routinely present at the mine site while it is actively operating or actively being closed, and who has responsibility for day-to-day operation of the facility with the cooperation and guidance of the EOR.

The owner must establish a written agreement with the EOR defining the responsibilities of the EOR and the owner and the scope of services to be provided by the EOR. The roles, responsibilities and authority of the EOR, the designer and the RP must be clearly defined in a facility operations maintenance and surveillance (OMS) manual. At a minimum, the OMS manual must be updated annually or with any major changes in roles and responsibilities (MAC, 2021).

Roles and responsibilities of the EOR must be consistent with the definition and roles described in the *2014 Mining Dams Bulletin* (CDA, 2014) and subsequent updates. The overarching professional responsibility of the EOR is to determine if the MWMF is in alignment with and meets applicable regulations, statutes, codes, guidelines and standards, by applying professional engineering judgement based on data available (CDA, 2016). The EOR holds the professional responsibility for the facility design, construction, operation and closure.

To support this responsibility, the EOR should conduct and report on annual inspections and be involved in the water management, water balance, operations, planning, closure, etc. (CDA, 2016). They should also participate in any risk assessments, audits or reviews of the facility. Measures should be in place to maintain continuity for the EOR or to effectively transition when succession is required.

The responsibilities of the RP should be defined in collaboration with the EOR and may include the following:

- Develops and implements the management plans for the MWMF.
- Coordinates the development and operation of facilities on the site with the EOR as well as internal and external resources.
- Develops succession plans for EOR and RP.
- Implements training programs for management activities associated with facilities.

- Implements or supervises the surveillance, inspection and monitoring and maintenance plan outlined in the OMS manual for the facility.
- In association with the EOR, defines quantitative performance objectives for operational and maintenance activities for inclusion in the OMS manual.
- As directed by the EOR, management of the water balance and annual reconciling of the water balance model and updating the water management plan.
- Reports to the mine manager regarding the status and performance of the management system for the facilities.

3.2.1. Options assessment

Table 3-1 defines requirements for options assessments. All options assessments must consider and explain how the concept of "best available technology" has been considered and applied in the selection process. Best available technology is defined as the site-specific combination of technologies and techniques that most effectively reduce the physical, geochemical, ecological and social risks associated with waste management during all stages of operations and closure and is economically achievable. Appendix D provides additional details about how to conduct an options assessment.

3.2.2. Risk assessment

Risk assessments are required not only to establish what the risks are, but also to put in place suitable risk treatment or management processes. Risk assessments are conducted early in the mine planning stage and are updated as a project proceeds through the assessment and regulatory processes. Table 3-2 defines requirements for risk assessments based upon facility classification and the assessment or regulatory stage.

Additional details about how to conduct risk assessments are provided in Appendix E.

3.2.3. Independent review

Review by experienced, technical peers can help to identify risks and opportunities, resulting in improvements in the performance and reliability of the MWMFs. Independent review provide owners with independent, objective, expert commentary, advice and potentially recommendations to support the planning, design, development, operation and closure of MWMFs and assist in identifying, understanding and managing the risks associated with MWMFs. Independent reviews are conducted by one or more qualified and experienced persons who have not been directly involved with the planning, design or operation of the mine waste management facility being reviewed.

INDEPENDENT REVIEW *is the systematic evaluation of all technical, management and governance aspects of a mine waste management facility across the life cycle conducted by competent, objective, third-party reviewers*

Table 3-3 describes specific requirements and recommendations for proponents to engage in independent review processes, which may range from the informal use of individual peer reviewers to the establishment of formal independent review boards comprised of recognized experts as may be appropriate for a given class of facility.

The purpose of an independent review is to:

- comment on the planning and design process, and overall effectiveness of the management system, monitoring programs, data analysis methodology and work performed by site team or contract consultants;
- provide the site team with practical guidance, perspective, experiences and standard/best practices from other operations;
- provide non-binding advice and guidance, while not directing the work or performing the role of the EOR;
- provide an independent assessment to senior mine management, the QP, the EOR, and to assessors or regulators whether the facility is being planned, developed, operated, and closed appropriately, safely and effectively;
- comment on the completeness and appropriateness of the risk assessment and understanding;

The objective of an independent review is to:

- facilitate informed management decisions for the management of mine waste to ensure risks are managed responsibly; and
- ensure that a third-party opinion regarding the risks and state of the MWMF and the implementation of the mine waste management system is available to all interested parties.

INDEPENDENT REVIEW BOARDS *are a group of peer reviewers appointed to provide independent, expert oversight, opinion, and advice to a proponent on the design, construction, operational management and closure of a MWMF.*

Where a formal independent review board is required, such review shall:

- be based upon terms of reference that are provided to assessors or regulators for review and comment, and that shall be developed or updated as required in consideration of risk assessments associated with the facility or updates or revisions to such risk assessments;
- be performed by independent subject-matter experts not currently involved in or responsible for the design, operation or construction of the facility; and
- be completed by a reviewer or group of reviewers of a size and make-up consistent with the complexity of the facility, in terms of risk, consequence and disciplines of substance.

For each year that independent reviews are conducted, an annual report of review activities must be produced for the mine owner and assessors or regulators that includes the following:

- a summary of the reviews conducted that year, including the number of meetings and attendees;
- whether the work reviewed that year meets the reviewers/panel's expectations of good practice and any recommendations that were provided by the reviewer or panel to the proponent, design engineer, QP, or EOR;
- any conditions that compromise integrity of an operating facility or occurrences of non-compliance with recommendations from the EOR; and

- signed acknowledgement by the review or members of the board, confirming that the report is a true and accurate representation of their reviews.

3.2.4. Mine waste management facility audits

An audit is the formal, systematic and documented examination of a mine waste management facility's conformance with the criteria or requirements identified in law, regulatory instruments and approved management plans. Audits evaluate and report on the degree of conformance with those criteria based upon the systematic collection and documentation of relevant evidence. Audits are not designed to determine the cause of deficiencies or to evaluate management system effectiveness.

Table 3-4 defines requirements for MWMF audits. To support audits, each MWMF must have designated quantitative performance objectives with measurable indicators. Pre-determined thresholds for the objectives and indicators should be defined along with comprehensive monitoring programs to manage short-term and long-term performance risks associated with the MWMF. Quantitative performance objectives, thresholds and monitoring programs should be defined by the EOR.

Where an external audit is required, it is expected that the auditors are independent of the company being audited. Auditors must maintain an objective viewpoint throughout the audit process to ensure findings and conclusions are based only upon evidence.

3.2.5. Water treatment system designs

Table 3-5 defines requirements for the design of water treatment systems. Specifically, it defines the testing requirements for demonstrating the feasibility and performance of proposed water treatment methods.

Table 3-1 *Planning and management practice – options assessments*

TABLE 3-1: PLANNING AND MANAGEMENT PRACTICES – OPTIONS ASSESSMENTS			
PHASE/STAGE	**CLASS I**	**CLASS II**	**CLASS III**
Planning phase/ assessment stage	Conduct options analysis to select the mine waste management approaches and locations. The analyses should be conducted by a qualified team hired by the proponent, including a designated design engineer, and using the methodology described in Appendix D and shall present how the selected option meets the objective of implementing the best available technology that is economically viable for a given project.	As per Class I.	Conduct options assessment as described for Class I & II but with the active involvement of regulators and affected First Nations with incremental review by an independent review board (IRB).
	Conceptual level designs are appropriate for screening of options and pre-feasibility designs are required for selecting a preferred alternative (See Appendix D).	As per Class I, but the team completing the assessment must include individuals who are independent of the proponent and the design team's firms. If an IRB has been established, it shall actively participate in the options assessment.	As per Class II with the addition that at least one workshop be held for interested parties and regulatory agencies in order to describe the options analysis process and to solicit input on the details of the analyses, the options selected for detailed analyses, the multiple accounts ledger used for the detailed analyses and the associated scoring and weighting factors proposed, as well as the sensitivity analyses proposed (See Appendix D for details). The results of the workshops must be reported as part of the assessment with explicit discussion of how divergent input (if any) was accounted for in the outcome of the assessment.
Planning phase/regulatory approvals stage	No further options assessment work is required. However, any assumptions, scoring and weighting made during the original options assessment shall be reviewed to ensure they remain valid and the preferred option is still supported as the best available technology that is economically viable for the facility. This review shall be done taking into consideration the feasibility-level design available at this stage and any additional characterization information and refinement of the mine plan or mine waste management plans.		
Development and operations phases	No further options assessment work will be required, unless modifications to the facility are proposed or the basis of the closure plan is re-considered. Any conducted options assessment shall include the EOR.	Option assessment required to support any unplanned modifications to the facility or its closure plan and, at least two years prior to planned closure, to reaffirm and select the closure plan. The closure plan analysis is to include and be based upon actual operational data, revised predictive modelling, current states of practice and substantive closure research on closure options. Alternatives assessment procedure to be conducted as described in planning phase.	As for Class II, in addition: the options analysis of the closure plan shall be re-affirmed at least: i) every five years; ii) whenever the facility owner considers substantive changes to the plan; or iii) two years in advance of planned closure. The EOR and the IRB shall participate in any conducted assessments. The assessments shall include the same other provisions identified for planning phase assessments.

Table 3-1: Planning and Management Practices – Options Assessments			
Phase/Stage	**Class I**	**Class II**	**Class III**
		The EOR shall participate in any conducted assessments.	
Closure phase/care and maintenance and active closure stages	No further options assessment work will be required, unless unplanned modifications to the facility are proposed or the basis of the closure plan is re-considered. Any conducted options assessment shall include the EOR	As per Class I.	As per Class II.
Closure phase/post-closure stage	No further options assessment work will be required, unless unplanned modifications to the facility are proposed or the basis of the closure plan is re-considered. Any conducted options assessment shall include the EOR	Options assessment required only in the event the installed closure design substantially fails to meet closure objectives such that the proponent is required to develop a new closure plan.	As per Class II.

Table 3-2 Planning and management practice – risk assessment

TABLE 3-2: PLANNING AND MANAGEMENT PRACTICES – RISK ASSESSMENT			
PHASE/STAGE	**CLASS I**	**CLASS II**	**CLASS III**
Planning phase/ assessment stage	Qualitative failure modes effects analysis (FMEA) of physical containment, geochemical containment for operations and closure.	Qualitative FMEA of physical containment, geochemical containment for operations and closure.	Semi-quantitative FMEA of physical containment, geochemical containment and other aspects of the project for operations and closure. Conduct a risk assessment workshop with interested parties and include results in the project proposal.
Planning phase/regulatory approvals stage	Qualitative risk assessment updated to address input received during EA consultation, advancement of site characterization, and advancement of the design.	Semi-quantitative risk assessment updated to address input received during EA consultation, advancement of site characterization, and advancement of the design.	As per Class II.
Development and operations phases	Qualitative risk assessment update with any significant changes to the project every five years, when quantitative performance objectives are not met, or a facility safety incident has occurred.	Annual risk assessment update to ensure that the quantifiable performance objectives and operating controls are current and manage the facility risks.	As per Class II.
Closure phase/care and maintenance and active closure stages	During or prior to care and maintenance stage conduct a semi-quantitative risk assessment of final detailed closure plan. Update the semi-quantitative risk assessment prior to seeking approval to move into post-closure stage.	As per Class I.	As per Class I, plus, include in the update a workshop for agencies and interested parties.
Closure phase/post-closure stage	Update semi-quantitative risk assessment if quantitative performance objectives are not achieved.	As per Class I.	Update semi-quantitative risk assessment if quantitative performance objectives are not achieved and at least once after 10 years of performance.

Table 3-3 Planning and management practice – independent review

TABLE 3-3: PLANNING AND MANAGEMENT PRACTICES – INDEPENDENT REVIEW				
PHASE/STAGE	**FACILITY TYPE**	**CLASS I**	**CLASS II**	**CLASS III**
Planning phase/ assessment stage	TMFs and HLFs	Independent review is **encouraged**.	Independent peer review of facility designs (including closure) and management plans **is required**. Establishment of a formal independent review board (IRB) will be required for this class if slurry tailings are present and may be required instead of a responsible person (RP) for HLFs if requested by the assessment agency.	Independent review by an independent review board (IRB) **is required** and should be engaged at the time of the options analyses. The membership and size of the review board are subject to approval by regulators, and those First Nations with an interest in the area affected.
	MRMFs	N/A	Same as TMFs and HLFs if MRMF triggers Class II due to geochemistry or human health and safety.	Same as TMFs and HLFs.
Planning phase/regulatory approvals stage	TMFs and HLFs	Independent review of facility designs and management plans by a Responsible Person **is required**.	Independent review of facility designs and management plans **is required** by either a RP or an IRB.	Independent review of facility designs and management plans **is required by the IRB**
	MRMFs	N/A	Same as TMFs and HLFs if MRMF triggers Class II due to geochemistry or human health and safety.	Same as TMFs and HLFs.
Development and operations phases	TMFs and HLFs	Independent review when a substantive change to the design, construction schedule or mode of operation of the TMF or HLF is proposed or has occurred. Dam Safety Review (DSR) is also required if tailings dam present.	Independent review, using an IRB as necessary, at least every 5 years or when a substantive change to the design, construction schedule or mode of operation of the TMF or HLF is proposed or has occurred. DSR is also required at least every 10 years or when a substantive change is proposed or has occurred.	IRB review at least every 5 years or when a substantive change to the design, construction schedule or mode of operation of the TMF or HLF is proposed or has occurred. DSR is also required at least every 5 years or when a substantive change is proposed or has occurred.
	MRMFs	N/A	Same as TMFs and HLFs if MRMF triggers Class II due to geochemistry or human health and safety.	Same as TMFs and HLFs.
Closure phase/care and maintenance and active closure stages	TMFs and HLFs	N/A	Review of closure design and construction is required by RP or IRB.	Review of closure design and construction is required by IRB.
		For dams that continue to provide storage of water or liquefiable tailings, refer to operations phase.		
	MRMFs	N/A	Same as TMFs and HLFs if MRMF triggers Class II due to geochemistry or human health and safety.	Same as TMFs and HLFs.
Closure phase/post-closure stage	TMFs and HLFs	N/A	Review by RP of closure performance at five-year intervals until conditions have stabilized and as required by regulators.	Review by IRB of closure performance at two to five year intervals until conditions have stabilized and as required by regulators.
		For dams that continue to provide storage of water or liquefiable tailings, refer to operations phase.		
	MRMFs	N/A	Same as TMFs and HLFs if MRMF triggers Class II due to geochemistry or human health and safety.	Same as TMFs and HLFs.

Table 3-4 *Planning and management practice – MWMF audit*

TABLE 3-4: PLANNING AND MANAGEMENT PRACTICES – MWMF AUDIT			
PHASE/STAGE	**CLASS I**	**CLASS II**	**CLASS III**
Operations phase	One external audit must be conducted within two years after start of operations and within two years after any change in ownership.	As per Class I, plus an audit should be conducted at least once every five years.	As per Class I, plus, an audit should be conducted at a minimum every three years.
Closure phase	One audit should be conducted one year after completion of the active closure stage.	As for Class I, plus a second audit should be conducted within 10 years of completion of the active closure stage.	As for Class I, plus routine audits should be conducted every 10 years.

Table 3-5 Planning and management practices - water treatment systems design

Table 3-5: Planning and Management Practices – Water Treatment Systems Design			
Phase/Stage	**Class I**	**Class II**	**Class III**
Planning phase/ assessment stage	Feasibility of any water treatment required to be demonstrated in the literature.	Physical/chemical treatment: Feasibility to be demonstrated in the literature. Biochemical and wetlands treatment: Feasibility to be demonstrated by similar case history or laboratory bench scale testing.	As per Class II.
Planning phase/regulatory approvals stage	Physical/chemical treatment: Feasibility of any water treatment required to be demonstrated by similar case histories or bench scale testing. Biochemical[4] and wetlands treatment: Feasibility to be demonstrated by bench scale testing.	Physical/chemical treatment: Feasibility to be demonstrated by bench scale testing. Biochemical and wetlands treatment: Feasibility to be demonstrated by bench scale testing.	Physical/chemical treatment: As for Class II. Biochemical and wetlands treatment: Feasibility to be demonstrated by bench and pilot scale testing.
Development and operations phases	Early implementation of field trials for any biochemical or wetlands treatment required for closure.	As per Class I.	As per Class I.
Closure phase	N/A	Demonstrated successful implementation of technology for water quality treatment.	As per Class II.

[4] Biochemical treatment generally includes both biological treatment plant and in ground bio-reactors used for treatment pH and metals.

4. Tailings management facilities

4.1. Introduction

This chapter provides guidance for tailings management facilities (TMFs). TMFs include any surface facility used for storing tailings, whether on their own or in combination with other mine wastes. This chapter does not address storage of tailings in underground workings. This chapter also addresses the design requirements for all dams on mine sites that are constructed for the purpose of containing contaminated water. If a dam contains only non-contact water the dam must be designed in accordance with the Canadian Dam Association guidance documents.

TMFs may rely on several engineered components to achieve physical and chemical confinement of tailings, associated pore and process water, and other co-disposed wastes. These components may include embankments, zoned dams, self-supporting structures, low permeability cores, filters and drains, structural shells, seepage cut-off trenches or walls, diversions, spillways, erosion armouring, surface drainage systems, covers, liner systems and other features.

TMFs progress through the project phases identified in Chapter 2 and may include a number of individual stages within the operations phase where the facility or specific components are progressively modified or expanded as the facility grows.

The guidance in this chapter applies, as appropriate, to the whole facility and individual components. The chapter provides guidance that is relevant to planning, developing, operating, and closing TMFs. Section 4.2 describes the classification of TMFs, which provides the framework for selecting design criteria, and planning and management practices that apply to each of the facility's phases. Section 4.3 provides general guidance and sections 4.4 to 4.7 provide specific guidance for key phases and stages in the life of a TMF.

The design for a TMF must be integrated with the overall mine development and tailings management plans for the project. The Yukon Plan Guide, especially Chapter 14, provides guidance about the content of tailings management plans. The guidance provided in that document complements the guidance provided in this chapter, which should be incorporated into any tailings management plans.

4.2. Facility classification

The classification of a TMF depends on the hazard it represents and the consequences of failure of the facility on human and natural environments. The classification will vary depending on a range of factors. These include the facility size, location, physical and geochemical properties of the stored waste and construction materials, sensitivity of the potentially affected environment, presence of private and public infrastructure, quality of construction and management, extent of traditional land use activities in areas potentially effected by a failure, and the resilience of the design. For TMFs that include dams, dam break analysis consistent with CDA recommendations is an integral part of completing the classification process.

In the context of the classifying TMFs, the boundaries between classes should not be interpreted as being definitive; numerical values associated with defining the classes are to be interpreted as indicative values only. Judgement and a holistic approach should be used where TMFs are proposed to have characteristics near the boundaries of classes.

In classifying TMFs, it should be recognized that the hazard and consequence of failure of a TMF may not be constant through its life phases. While TMFs are generally expected to represent a peak hazard level at their full build-out, the classification process must examine all phases and stages to determine the critical phase and stage for classification purposes.

Selection of appropriate design criteria and implementation of appropriate planning and management practices can help to reduce the likelihood and the consequences of failure for TMFs. The application of appropriate criteria and implementation of appropriate practices is intended to result in acceptable levels of residual risk from the operation and closure of the facility.

Proponents are required to define the classification for any proposed TMF in accordance with the criteria and thresholds provided in Table 4-1. Although filtered tailings facilities are classified using the criteria and thresholds in Table 4-1, they are designed in accordance with Table 5-2 when an embankment for physical stability is not required. The classification for TMFs that include dams[5] begins with classification of the dams in accordance with the *Dam Safety Guidelines 2007 – 2013 Edition* (CDA. 2013) and the *Mining Dams: Application of 2007 Dam Safety Guidelines to Mining Dams* (CDA. 2014). However, the CDA classification for dams is one of many criteria used in this guideline for classification of TMFs, and may not be the critical factor in the classification.

All TMFs with one or more dams classified in the Very High and Extreme CDA categories fall into Class III in this guidance. TMFs with dams classified in the Significant and High CDA categories may fall into Class II, unless they have another facility characteristic that raises them to Class III. TMFs with dams classified in the Low CDA category may fall into Class I in this guidance, unless they have another facility characteristic that raises them to Class II or III.

[5] Dams are defined in the CDA Technical Bulletin Application of Dam Safety Guidelines to Mining Dams.

Table 4-1 *Tailings and combined tailings and waste rock management facility classification*

TABLE 4-1 TAILINGS AND COMBINED TAILINGS AND WASTE ROCK MANAGEMENT FACILITY CLASSIFICATION				
FACILITY CHARACTERISTICS		FACILITY CLASS		
CHARACTERISTIC	MODIFYING CONSIDERATIONS	CLASS I	CLASS II	CLASS III
CDA Classification of Highest Consequence Dam		LOW	SIGNIFICANT or HIGH	VERY HIGH or EXTREME
Maximum planned height of facility (above natural ground) [6]	If slurry / thickened tailings or liquefiable waste	Less than 10 meters[7] or in-pit storage[8]	Between 10 and 100 m	More than 100 m
	If filtered tailings and non-liquefiable waste	Less than 50 m or in-pit storage	Between 50 and 200 m	More than 200 m
Volume of tailings		Less than 1 million m^3 or in-pit storage	Between 1 million and 50 million m^3	More than 50 million m^3
Human health and safety		Other than the temporary presence of mine workers carrying out their duties, there is no identifiable population at risk from a failure of the facility.	People, other than mine workers carrying out their duties, are only temporarily in the failure hazard zone for the facility (e.g., seasonal use, passing through on transportation routes, recreational activities).	People (including mine workers) permanently live or work in the failure hazard zone.
Presence of permafrost potentially affecting waste confinement and stability		No permafrost present under critical elements of the facility.	Permafrost present and ice-rich permafrost removed to thaw stable materials under critical elements of the facility.	Ice-rich permafrost present and not fully removed under critical elements of the facility.
Geochemistry of waste materials and construction materials		Non-acid-generating (NAG) waste and construction materials only.	Potentially acid-generating (PAG) waste materials present but PAG materials are stored in-pit storage or unlikely to be mobilized in the event of a perimeter containment failure.	PAG waste present and likely to be mobilized in the event of a perimeter containment failure
Predicted quality of stored water (for phase/stage with most adverse water quality)		Water stored in facility predicted to have contaminant concentrations (exclusive of total suspended solids, or TSS) that are less than 10x applicable receiving water quality guidelines or site-specific water quality objectives for all contaminants of concern (COCs).	Water stored in facility predicted to have concentrations for one or more COC (exclusive of TSS) that is between 10x and 500x applicable receiving water quality guidelines or site-specific water quality objectives.	Water stored in facility predicted to have concentrations for one or more COC (exclusive of TSS) that is greater than 500x applicable receiving water quality guidelines or site-specific water quality objectives.
Effluent management requirements		Protection of receiving water does not require active or passive management of water discharges other than sediment control during the development or operations phases.	Protection of receiving water requires active or passive management of water discharges during the operations phase and during the care and maintenance and active closure stages of the closure phase, and passive management of water discharges during the post-closure stage.	Protection of receiving water requires active management of water discharges in the long-term during the post-closure stage.

[6] Measured as the maximum vertical thickness of tailings or waste above natural ground.
[7] Measured as the elevation difference between the crest of the retaining facility and the lowest point on the downstream toe of the retaining facility.
[8] In-pit storage means that all waste is stored in mined-out pits below the elevation of the lowest point on the pit rim. In-pit storage must provide both geologic and hydro-geologic containment.

Table 4-1 Tailings and Combined Tailings and Waste Rock Management Facility Classification				
Facility Characteristics		Facility Class		
Characteristic	Modifying Considerations	Class I	Class II	Class III
Surface water diversions		Operational water diversions where failure of the diversions would not affect containment of tailings or other mine waste	Operational water diversions where failure cannot affect containment of tailings or other mine waste	Closure water diversions where failure may affect containment of tailings or other mine waste
Surface water storage volume (design seasonal maximum storage)	During any of the development and operations phases and the care and maintenance and active closure stages	Less than 20 thousand m^3	Between 20 thousand and 5 million m^3	More than 5 million m^3
	During post-closure stage	No proposed storage, drained and capped facility		Permanent water cover required and waste material is stored above bedrock confinement

4.3. Guidance for planning and design

4.3.1. Introduction

The planning and design process for TMFs is generally iterative, with increasing levels of planning and design as the project proceeds. Designs for TMFs must address all life phases and stages and all components of the TMF.

At all levels of design, the designs should all incorporate “design for closure” principles and therefore the initial design should include closure option selection and conceptual closure designs as these will inform decisions about the TMF design, construction and operation. For both assessment and regulatory applications, the designs must demonstrate that the proposed closure design can achieve the defined closure outcomes and objectives. It is also necessary to provide evidence that an unplanned permanent closure at the most critical time in the operation of the facility can be accommodated.

A specific issue in the Yukon is the effect of cold temperatures on the operation and maintenance of TMFs including appurtenant structures and facilities. Experience with cold regions issues is critical to ensure appropriate planning and design for TMFs. In addition to the consideration of current climatic conditions, it is critical that TMFs are planned, designed, built and operated to withstand projected impacts of climate change.

Specifically, the issue of frost heave and subsequent thaw in earth structures, and ice and aufeis developing in water conveyance and storage facilities requires consideration in selecting the design criteria for TMFs. Ice and aufeis may be particularly important in relation to storage capacities, discharge capacities, and freeboard allowances which may be affected by the potential for loss of capacity due to ice and aufeis development. Cold temperatures may also be a factor in the suitability or performance of liner systems, the operation of gates and valves, and may lead to specific design criteria to ensure appropriate performance for critical elements of TMFs.

Further guidance for conducting designs is provided in Appendix C.

4.3.2. Design objectives, requirements and criteria

Table 4-2 summarizes the key design requirements and criteria for TMFs that fall into each facility classification. These are minimums for each facility classification. TMFs that contain only filtered tailings are to be designed in accordance with Table 5-2.

During initial planning for a TMF, objectives and criteria should be established for all stages from construction through post-closure. Objectives and criteria often vary between the operations phase and the closure phase with the closure phase being more stringent. They may also vary for each operational stage depending on the hazards and the duration of the stage. Closure objectives are particularly important in the initial planning for TMFs and are addressed in Section 4.7.

Some common types of criteria that are normally defined for a TMF are identified below:

- Geotechnical criteria – factors of safety for static and seismic loading; acceptable deformations resulting from seismic loading, compression, consolidation and thaw consolidation; minimum tailings beach width; minimum compaction achieved; placement water contents; gradation limits for construction materials; minimum zone widths or thicknesses; and pore water pressure limits.
- Hydrologic criteria – return period and duration for design rainfall events; return period for seasonal snow accumulation and melt; antecedent conditions for runoff calculations; criteria to establish runoff volumes; return period of inflow floods; freeboard criteria for the TMF and discharge conveyance channels; spillway capacity and elevations; normal and maximum water levels; significant wave run up return period; water storage capacity; and climate change adjustment factors.
- Tailings storage conditions – constraints on tailings storage; tailings density, percent solids, or water content; percent sulphides; exposure time for reactive tailings; ice entrainment; and requirements for lining or covering tailings.
- Water quality criteria – effluent discharge standards for contaminants of concern and receiving water quality guidelines or site-specific receiving water quality objectives for contaminants of concern.
- Other engineering and construction criteria including cold regions criteria and requirements and landform criteria – describe approaches and criteria that should be used to design safe effective and durable facilities and stable post-

closure landforms that meet closure and land use objectives (e.g. acceptable erosion rates, progression of slopes, etc.).

Closure water quality criteria should conserve, to the extent reasonable and practical, assimilative capacity in aquatic ecosystems. Closure design criteria for land affected by tailings need to consider physical and chemical stabilization as well as land use objectives. Landform design aspects are important considerations during the closure design process. Mine operators are encouraged to include landform design aspects in their closure plans and to develop a series of closure design criteria for their inclusion. Criteria for allowable long-term erosion losses should be established as part of the landform design considerations. Where closure plans include covers, they should be designed in accordance with guidance provided in *Cold Regions Cover System Design, Technical Guidance Document* (MEND Report 1.61.5c. July 2012) or other relevant references.

In addition to meeting the requirements and criteria specified in Table 4-2, the planning, development, operation, and closure of TMFs must also comply with Chapter 14 of the *Plan Requirement Guideline for Quartz Mining Projects* (Government of Yukon 2013).

Table 4-2 *Minimum design requirements for tailings management facilities*

TABLE 4-2: MINIMUM DESIGN REQUIREMENTS FOR TAILINGS MANAGEMENT FACILITIES			
CATEGORY	**CLASS I**	**CLASS II**	**CLASS III**
CONSTRUCTION CONSTRAINTS	No upstream or modified centerline construction permitted.	No upstream construction permitted.	No upstream or modified centre line construction permitted
	Conduits through containment structures not permitted		
DESIGN CRITERIA **Development, operations and closure phases**	Use the standards presented below: **Seismic design:** Operations: 1/2475 AEP Closure: same as operations	Use most recent CDA Mining Dam Safety Guidelines for the High Dam Classifications for CDA passive closure scenario. Current standards are listed below (CDA, 2014): **Seismic design:** Operations: 1/2475 AEP Closure: 1/2 between the 1/2475 and 1/10,000 AEP or MCE Also: Conduct a fault study and develop acceleration time histories for design analyses	Use most recent CDA Mining Dam Safety Guidelines for the Extreme Dam Classifications for CDA passive closure scenario. Current standards are listed below (CDA, 2014): **Seismic design:** Operations: 10,000yr EDGM or MCE Closure: Same as operations Also: Conduct a fault study and develop acceleration time histories for design analyses
	Flood design: IDF for Operations – 1/3 between the 1/975 and PMF for the critical duration event IDF for Closure – same as operations	**Flood design:** IDF for Operations - 1/3 1,000yr and PMF for the critical duration event IDF for Closure – 2/3 between the 1/1,000 yr. and PMF for the critical duration event	**Flood design:** IDF for Operations: PMF for the critical duration event IDF for Closure: same as operations
	FACTORS OF SAFETY Use most recent CDA Mining Dam Safety Guidelines Current Standards (CDA, 2014)		
	Catchment area for determining IDF flood: TMF catchment area plus the catchment areas of the surface water diversions in the event the surface water diversions are designed to a smaller design flood than the dam spillway design flood		

Table 4-2: Minimum Design Requirements for Tailings Management Facilities			
Category	**Class I**	**Class II**	**Class III**
DESIGN METHODS FOR SLURRY IMPOUNDMENT EMBANKMENTS[9] **Development and operations phases**	**DESIGN METHODS** Static analyses: • Average shear strength properties • Expected phreatic surfaces • Limit equilibrium methods of stability calculations Dynamic analyses • Average shear strength properties • Pseudo-static calculations for earthquake design • Deformation analyses using simplified method such as Newmark; demonstration that deformations are acceptable • Post-earthquake analysis with residual strength parameters	**DESIGN METHODS** Static analyses: • As for Class I, except use lower bound shear strength properties Dynamic analyses: • As for Class I, except use lower bound shear strength properties	**DESIGN METHODS** Static analyses: • based upon the results of finite element modelling using constitutive soil behaviour models populated with lower bound input parameters and expected phreatic surfaces Dynamic analyses: • Static model subject to time or frequency domain analyses for design and deformation analyses • Modelling utilizes undrained and residual shear strength, modulus and modulus degradations curves • Must demonstrate that resulting deformations are acceptable
PERMAFROST CONSIDERATIONS **Development and operations phases**	**FIELD DATA COLLECTION REQUIREMENTS** Identify presence and characteristics of permafrost in accordance with NRC guidelines and Appendix B	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 15 m depth, and ground ice content classification as per NRC guidelines	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 20 m depth and ground ice content classification as per NRC guidelines.
	DESIGN REQUIREMENTS	**DESIGN REQUIREMENTS**	**DESIGN REQUIREMENTS** Design to include: • Settlement of thawed permafrost, due to both thawing of ground ice and long-term consolidation • Un-drained failure of thawed fine grained permafrost • Potential creep of ice-rich permafrost under load • Two-dimensional thermal analysis • Include climate change effects.

[9] Note that design methods for dry-stack filtered tailings are as for Heaps in Table 5-2

Table 4-2: Minimum Design Requirements for Tailings Management Facilities			
Category	**Class I**	**Class II**	**Class III**
WATER MANAGEMENT **Development and operations phases**	SURFACE WATER DIVERSIONS **Design flood:** IDF for operations – 200yr IDF for closure – same as operations	SURFACE WATER DIVERSIONS **Design flood:** IDF for operations – 200yr IDF for closure – 500yr	SURFACE WATER DIVERSIONS **Design flood:** IDF for operations – 500yr IDF for closure – 1,000yr
	POND WATER CAPACITY REQUIREMENTS **Pond freeboard to spillway invert:** EDF for operations: 50yr critical duration event EDF for closure: not required **Pond freeboard without spillway:** Operations: spillway if required for management of IDF Closure: water storage not permitted	POND WATER CAPACITY REQUIREMENTS **Pond freeboard to spillway invert:** EDF for operations: 100yr critical duration event EDF for closure: 200yr critical duration event **Pond freeboard without spillway:** Operations: spillway if required to manage IDF Closure: Spill is required.	POND WATER CAPACITY REQUIREMENTS **Pond freeboard to spillway invert:** EDF for operations: 200yr critical duration event EDF for closure: 200 yr. critical duration event **Pond freeboard without spillway:** As per Class II
	SEDIMENT DETENTION POND CAPACITY In the event required, see requirements in Section 4.0, Table 4-2		

4.3.3. Guidance for site and method selection

As indicated in Table 3-1, an options assessment is required as part of planning for management of tailings. The options assessment is the basis for the selection of the sites and methods for managing tailings that will be produced. Detailed information on how to conduct options assessments is presented in Appendix D.

As the method of tailings storage and the location of a TMF are interrelated, they must be considered together when selecting a tailings management option. The identification of tailings storage methods and sites should begin with consideration of a broad range of options for storage methods including impoundments for slurry, thickened or paste tailings, tailings dry-stacks, storage in pits, and any other relevant methods. While the range of sites will be constrained by the methods selected, a broad range of sites should also be identified for each possible method. The process must explicitly identify how best available technology has been considered for the specific project.

The identification and analysis of options for TMFs must include the following:

- Consider at least one geologic containment option and retain that option in the analysis at least through the comparative analysis step.
- Where possible, avoid permanent retention of saturated tailings behind dams. Options analyses must consider the long-term risks associated with such storage methods.

4.3.4. Site characterization

Designs for TMFs should include site characterization that meets the requirements defined in Appendix B. The level of detail for characterization of the site will increase as the level of design increases, with additional effort undertaken to collect more site-specific data as the design progresses.

For earlier levels of design, where site-specific data are less comprehensive, site characterization should be based on conservative assumptions about conditions, particularly the extent or presence of adverse conditions. Where potentially adverse conditions may fundamentally impact the feasibility of the proposed design, more advanced site characterization may be required to support early level designs.

For all stages of design, characterization of environmental and site conditions must be completed in sufficient detail to support prediction of potential effects arising from development, operation and closure of the TMF, and completion of any modelling and analyses for the design of the TMF and each of its components.

For geotechnical site characterization of foundations, site investigations must at least conform to the site investigation guidelines issued by the Association of Professional Engineers and Geoscientists of British Columbia.

4.3.5. Facility design

The design of TMFs must be carried out by qualified professional engineers and environmental scientists. The overall design usually involves several different disciplines of engineering, geoscience, and environmental scientists. As such, the design is normally carried out by a team of qualified professionals who are responsible for completing the design, and producing the technical specifications, drawings, and management plans.

Table 2-1 in Appendix C provides guidance for the design process as it is refined over time; it is iterative and the design basis document is updated throughout the design process.

Design documents should also identify further design requirements, including additional levels of design and any management plans required to ensure construction and operation will be in compliance with the objectives, assumptions and constraints.

Design of TMFs must include analysis and supporting modelling to determine whether a liner system is required to address potentially unacceptably adverse water quality impacts in the receiving environment. The need for liner systems should be based on fate and transport analyses of unlined facilities and with the objective of predicting the impacts of the TMF on groundwater and surface water resources. Where unacceptable impacts are expected to occur, fate and transport analyses for TMF's with the inclusion of liners and other seepage mitigation technologies should be completed. In the case of liners, this should include reasonable assumptions for the following parameters and calculation methodologies:

- Hydraulic head on the foundation or liner system if proposed
- Expected number and size of perforations in constructed geomembrane liner systems for the anticipated construction quality assurance
- Upper bound hydraulic conductivity values for any natural clay or silt layers or liners proposed[10]
- Seepage losses using established analytical formula or models
- Upper bound hydraulic conductivity analyses based on field measurements for the unsaturated zone including measurements below the liner system
- Saturated or unsaturated seepage analyses between the foundation liner and the groundwater table
- Reasonable allowance for mixing of seepage and groundwater

The above analyses may have to be repeated with different liner systems until a suitable system is selected. The latest literature should be consulted to estimate the quantity and size of defects expected in a geomembrane liner in a mining application.

4.3.6. Risk assessment

The designs for the TMF and its components must include systematic risk assessment approaches to characterize risks that the TMF will not perform as expected. The purposes of risk assessment are to evaluate the risks, modify design approaches, develop mitigation measures that minimize the risks to an acceptable level and characterize immitigable residual risks.

The level of effort for risk assessment will vary depending on the severity of hazards associated with each TMF, but in all cases the TMF design must consider and address the results of a risk assessment using methodologies described in Appendix E. This does not exclude implementation of additional risk assessment methodologies as

[10] Laboratory tests results to be adjusted for expected “as-built” field conditions.

appropriate for each class of facility. The risk assessment process completed in accordance with Appendix E must be facilitated by a suitably experienced risk assessment professional, and include the participation of both the proponent's experts and representatives of interested parties.

Risk assessments should be completed incrementally as the design level evolves; however, a comprehensive assessment should be completed in association with the feasibility design.

4.4. Guidance for construction

4.4.1. Construction plan

A construction plan for describing the construction management and supervision, sequence/schedule, temporary facilities, environmental management, quality assurance/quality control, emergency management, change management and requirements for commencing operations must be prepared and submitted with regulatory applications. The role of the EOR should be clearly defined through all stages of construction.

Detailed requirements for construction plans are described in Appendix F.

4.4.2. As-built report

As-built reports must be provided upon completion of construction of a TMF, and for any modification or expansion of the TMF or any of its retaining, containment or conveyance components. Each as-built report must be certified by the EOR and must contain:

- A complete set of drawings depicting the as-built condition of all components of the tailings management facility.
- Results of the construction QA/QC programs including results of inspections and testing. Identify any non-compliant test results and describe how these were addressed.
- Description of issues or concerns encountered during construction.

- Records of changes implemented during construction, including approvals for the changes.
- Any recommendations from the EOR relating to operations, maintenance and surveillance for the tailings management facility or any of its components.

4.5. Guidance for operation

4.5.1. Operations, maintenance and surveillance

All TMFs must have an operation, maintenance and surveillance (OMS) manual that describes the operational actions and approaches that will be in place to ensure compliance with the TMF design. Operational decisions about water management, tailings deposition and staged construction activities must be guided by the OMS manual. The manual must clearly define the overall responsibility of a corporate executive in charge of tailings management considerations and the ongoing role of the EOR throughout operations.

The main sections of an OMS manual will usually include roles and responsibilities, facility description, operation, maintenance, surveillance, and emergency planning and response.

The OMS manual should identify site-specific issues of importance, including the trigger levels for instrumentation. The OMS manual must be updated on a regular basis, and copies provided to regulatory agencies.

OMS manuals must be prepared in accordance with *Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities* (Mining Association of Canada. 2021). Operations managed by Mining Association of Canada (MAC) members will be subjected to the MAC auditing protocol. Companies who are not MAC members must conduct auditing that meets the requirements of the MAC guidance.

4.5.2. Environmental monitoring and reporting

Environmental monitoring and reporting for the operational phase of the TMF must be addressed in an overall environmental monitoring plan for the complete project.

Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

For projects that include TMFs, monitoring programs need to include data to support the following during the operations phase:

- Development, calibration and refinement of water balance model and contaminant load model
- Evaluation of water balance and contaminant loading outcomes
- Evaluation of any contaminant-related effects in the aquatic, terrestrial or atmospheric environment.
- Evaluation of any physical effects on wildlife or wildlife habitat (including birds).

4.6. Guidance for closure

4.6.1. Introduction

As described in Section 3.2, planning for closure for a TMF must be initiated in parallel with the TMF design, applying the design-for-closure concept.

The closure plan for a TMF must meet the general requirements in the *Yukon Closure Guide* and *Yukon Closure Policy*, and be part of the integrated site reclamation and closure plan (RCP). The closure plan must address all closure types and phases including temporary closure, progressive reclamation during operations, interim care-and-maintenance, active closure and post-closure.

While early initiation of reclamation and closure planning is critical, an RCP must be refined throughout the life of the TMF as specific information is gathered and lessons are learned through operations, reclamation research programs and monitoring programs. Updates should include any changes and refinements to proposed closure measures. They should also present designs at increasing levels of detail as the development of the TMF progresses, so that detail sufficient for construction is available before closure implementation.

Closure plans submitted to support environmental assessment and permitting processes must clearly describe practical and feasible approaches for achieving the defined closure objectives. Options for closure of the TMF and its components should be evaluated as part of the initial selection of the tailings management method and site, as described in Section 4.3.3.

Immediately prior to closure, the performance of any liner system used must be assessed as part of the inspections and reviews required in accordance with Table 3-3. In the event these inspections and reviews conclude the performance is inadequate, corrective measures need to be designed and installed. Corrective measures could include, but are not limited to, seepage collection systems and low-permeability soil or geomembrane covers.

Environmental monitoring and reporting for the closure phase of the TMF must be addressed in an overall environmental monitoring plan for the complete active closure project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program. In general, monitoring during the closure phase will be a continuation of the operational monitoring program with refinements to address the changes in the types of activities that will be occurring. Water balance, contaminant loading and effects on wildlife and wildlife habitat will continue to be important monitoring issues for TMFs during the closure phase. If allowable long-term erosion losses are established as part of the landform design considerations, monitoring plans will need to provide information about erosion losses.

4.6.2. Risk assessment

Initial risk assessments from earlier phases of the TMF need to be updated during the closure phase, as described in Table 2-1. Generally, the use of FMEA approaches are acceptable; however, Class III TMF dams that will store liquefiable tailings, or water in the long-term, require a more detailed risk assessment prior to closure for both the embankment and the spillway. Appendix E provides the requirements when conducting risk assessments for MWMFs.

For Class III, in addition to the FMEA for the overall site closure, an event tree analysis is required for the embankment and the spillway to ensure any long-term post-closure risks due to evolution of the slopes and spillways in response to long-term drivers are identified and addressed in the design. In some instances where long-term performance cannot be sufficiently estimated for the design interval of slopes and spillways, it may be necessary to include redundant features or infrastructure elements to provide necessary long-term resilience.

4.7. Guidance for post-closure

The closure plan for a TMF must describe the activities and requirements for the post-closure stage. The closure plan should clearly define the duration of the post-closure stage. The post-closure stage continues until the site has achieved self-sustaining, long-term stable conditions comparable to surrounding terrain, without human intervention. TMFs that require ongoing monitoring and maintenance of water retaining and conveyance structures must consider very long duration post-closure stages.

4.7.1. Maintenance and surveillance

Each TMF closure plan should be accompanied by a maintenance and surveillance plan for the post-closure period. The plan should describe what activities would be undertaken to ensure that conditions continue to achieve closure objectives and criteria. At a minimum, the closure maintenance and surveillance plan should address the following operational aspects:

- Site security;
- Dam inspections;
- Operations of water management systems including any seepage collection, treatment and discharge systems;
- Water quality discharge and receiving water standards and other water management requirements such as required water levels;
- Identification of potential risks;
- Monitoring; and
- Adaptive management and contingency plans.

4.7.2. Monitoring and reporting

Water balance, contaminant loading and effects on wildlife and wildlife habitat will continue to be important monitoring issues for TMFs during the post-closure stage.

Environmental monitoring and reporting for the post-closure stage of the tailings management facility must be addressed in an overall environmental monitoring plan for the complete post-closure project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

Post-closure monitoring for tailings management facilities must provide information about contaminant loading and migration. It should also address wildlife and wildlife habitat to ensure that reclamation objectives are achieved. If the post-closure stage for the TMF includes active water management, the monitoring program will need to continue providing information to understand water balance and the program will generally be a continuation of the active closure stage-monitoring program with refinements to address the changes in the types of activities that will be occurring.

Post-closure monitoring for TMFs must continue for as long as the facilities present any physical or chemical risk.

5. Heap leach facilities

5.1. Introduction

This chapter provides guidance for heap leach facilities (HLFs). Heap leach facilities include ore stacked on to heap leach pads, leaching solution conveyance systems and containment of barren and pregnant solutions in internal (within the heap pile) or external ponds, water management facilities and can also include water treatment systems. Batch or vat leaching operations are not within the scope of this document.

The guidance in this chapter applies, as appropriate, to the whole facility and individual components. The chapter provides guidance that is relevant to planning, developing, operating, and closing HLFs. Section 5.2 describes the classification of HLFs, which provides the framework for selecting design criteria, and planning and management practices that apply to each of the facility's phases. Section 5.3 provides general guidance and sections 5.4 to 5.7 provide specific guidance for key phases and stages in the life of a HLF.

HLFs progress through the project phases identified in Chapter 2 Normally, HLFs are operated as closed systems with no effluent discharge during operations. During closure, rinsing and drain-down of heap fluids is a necessary task that normally requires treatment of the release fluids.

Heap leach pads (HLPs) are pads on which ore is stacked and then leached to remove the target minerals. The HLPs can either be dedicated pads on which the ore is permanently stacked and stored, or reusable with the ore removed after leaching and rinsing for disposal elsewhere. The pads can be constructed on relatively flat prepared ground or within valleys with a retaining embankment. All HLPs in the Yukon are required to be lined.

HLFs with external solution storage typically have three types of ponds; a pregnant solution pond for collecting the leach solution, an overflow pond for storm leachate and runoff during extreme storm events, and a barren pond used to store solution for application to the heap. Other terminologies are also used to describe these ponds; for example, in copper heap-leaching the leached solution pond is referred to as a pregnant leach solution pond and the pond containing the solution to be applied is referred to as a raffinate pond. Overflow ponds are also referred to as event ponds or emergency ponds. In some projects, intermediate solution ponds are included for the circulation of solution with low metal concentrations. HLFs with solution storage within the heap (e.g., valley-fill HLP with in-heap pond) generally require additional external ponds for excess fluid storage and normally have barren solution stored in tanks within an associated processing building. Depending on the water balance for the project, operation of a HLF may require make-up water supplies; these are often sourced from event or emergency ponds, but may also be a separate purpose-built pond.

The guidance in this chapter applies, as appropriate, to the whole facility and individual components. The chapter provides guidance that is relevant to planning, developing, operating, and closing HLFs. Section 5.2 describes the classification of HLFs, which provides the framework for selecting design criteria, and planning and management practices that apply to each of the facility's phases. Section 5.3 provides general guidance and sections 5.4 to 5.7 provide specific guidance for key phases and stages in the life of a HLF.

Initial planning for heap leach facilities must follow a design-for-closure approach to demonstrate how the facilities will meet the relevant standards for all project phases and achieve suitable long-term performance. This approach will require additional planning and design effort at each phase; the designs and plans for each phase must advance as the development of the project progresses.

The design for a HLF must be integrated with the overall mine development and operations plan for the project. The Yukon Plan Guide, particularly Chapter 13, provides guidance about the content of heap leach facility plans. The guidance provided in that document complements the guidance and standards provided in this chapter, which should be incorporated into any heap leach and process facility plan.

5.2. Facility classification

The health and safety, environmental, cultural and other hazards associated with HLFs will vary depending on a range of factors including size, location, material properties and in some cases community resilience. Requirements for design, construction, operation and closure help reduce risks associated with HLFs. Reducing risks to acceptable levels requires application of more stringent requirements and standards for projects that have higher hazard than for those with lower hazard.

In the context of the classifying HLFs, the boundaries between classes should not be interpreted as being definitive; numerical values associated with defining the classes are to be interpreted as indicative values only. Judgement and a holistic approach should be used where HLFs are proposed to have characteristics near the boundaries of classes.

In classifying HLFs, it should be recognized that the hazard and consequence of failure of a HLF may not be constant through its life phases. While HLFs are generally expected to represent a peak hazard level at their full build-out, the classification process must examine all phases and stages to determine the critical phase and stage for classification purposes.

Selection of appropriate design criteria and implementation of appropriate planning and management practices can help to reduce the likelihood and the consequences of failure for HLFs. The application of appropriate criteria and implementation of appropriate practices is intended to result in acceptable levels of residual risk from the operation and closure of the facility.

Proponents are required to define the hazard classification for any proposed HLF in accordance with the criteria and thresholds provided in Table 5-1. The classification for HLFs that include dams[11] begins with classification of the dams in accordance with Table 4-1. However, the classification for dams is one of many criteria used in this guideline for classification of HLFs and may not be the critical factor in the classification.

[11] Dams are defined in the CDA Technical Bulletin Application of Dam Safety Guidelines to Mining Dams.

All HLFs with one or more dams classified in the Very High and Extreme CDA categories fall into Class III in this guidance. HLFs with dams classified in the Significant and High CDA categories may fall into Class II, unless they have another facility characteristic that raises them to Class III. HLFs with dams classified in the Low CDA category may fall into Class I in this guidance, unless they have another facility characteristic that raises them to Class II or III.

Table 5-1 *Heap leach facility classification*

TABLE 5-1: HEAP LEACH FACILITY CLASSIFICATION[12]			
FACILITY CHARACTERISTICS	FACILITY CLASS		
CHARACTERISTIC	CLASS I	CLASS II	CLASS III
Maximum vertical thickness of stacked ore[13]	Less than 50 metres	Between 50 metres and 140[14] metres	More than 140 metres
Maximum leach solution application rate	1,000 m^3/hr or less	Between 1,000 m^3/hr and 5,000 m^3/hr	5,000 m^3/hr or greater
Solution storage	All free solution storage provided in external ponds.	Some or all free solution storage provided by an internal pond within the ore heap.	
Presence of permafrost	No permafrost present under critical elements of the facility.	Permafrost present and ice-rich permafrost removed to thaw stable materials under critical elements of the facility.	Ice-rich permafrost present and not fully removed under critical elements of the facility.
Geochemistry of ore and residue	NAG ore and residue only.	PAG ore or residue present, but unlikely to be mobilized in the event of heap failure.	PAG ore or residue present, and likely to be mobilized in the event of heap failure.
Predicted water quality of heap drainage after completion of detoxification	Water released from HLF **after detoxification and rinsing** predicted to have contaminant concentrations (before water treatment) that are less than 10x applicable receiving water quality guidelines or site-specific water quality objectives for all contaminants of concern (COCs).	Water released from HLF **after detoxification and rinsing** predicted to have concentrations for one or more COC (before water treatment) that is 10x or more, but less than 500x, above applicable receiving water quality guidelines or site-specific water quality objectives.	Water released from HLF **after detoxification and rinsing** predicted to have concentrations for one or more COC (before water treatment) that is 500x or more above applicable receiving water quality guidelines or site-specific water quality objectives.
Effluent management requirements	Protection of receiving water requires: (a) active or passive management of water discharges during operations, care and maintenance and active closure; or (b) management at closure not required	Protection of receiving water requires: (a) active or passive management of water discharges during operations, care and maintenance and active closure; or (b) passive management of water discharges during post-closure phase.	Protection of receiving water requires active management of water discharges in the long-term during the post-closure phase.
Leaching conditions			Leaching conducted with acidic reagents (i.e. solutions with a pH<5).
Human health and safety	Other than the temporary presence of mine workers carrying out their duties, there is no identifiable population at risk from a failure of the facility.	People, other than mine workers carrying out their duties, are only temporarily in the failure hazard zone for the facility (e.g., seasonal use, passing through on transportation routes, recreational activities).	People (including mine workers) permanently live or work in the failure hazard zone.

[12] This classification is for the heap only. The associated ponds, including a valley leach containment dam, are to be classified in accordance with Table 3-1.
[13] Measured as the maximum vertical thickness of stacked ore above the completed liner.
[14] In this depth range, key components become significantly more complicated: (a) conventional drainage pipes collapse and so an alternative system is generally required, and (b) conventional liner systems require upgrades to function reliably under the higher loads.

5.3. Guidance for planning and design

5.3.1. Introduction

The key components of a HLF design include the initial construction, designs for staged expansion during the operating period, stacking plans that describe how the ore is stacked and leached over time, the closure activities which may include detoxification of the remaining solutions in the heap, the grading and capping of the spent ore, and the long-term water management and maintenance. The design process is iterative, and results in increasing levels of planning and design detail as a project proceeds. Designs for HLFs must address all life phases and stages and all components of the HLF.

All designs should all incorporate "design for closure" principles and therefore the initial design, the closure option selection and conceptual closure designs should be done in parallel.

A specific issue in Yukon is the effect of cold temperatures on the operation and maintenance of HLFs including appurtenant structures and facilities. Experience with cold regions' issues is critical to ensure appropriate planning and design for HLFs. In addition to the consideration of current climatic conditions, it is critical that HLFs are planned, designed, built and operated to withstand projected impacts of climate change.

Further guidance for conducting designs is provided in Appendix C.

5.3.2. Design objectives, requirements and criteria

Table 5-2 summarizes the key design requirements and criteria for HLFs that fall into each facility classification. These are minimums for each facility classification.

During initial planning for a HLF, objectives and criteria should be established for all stages from construction through post-closure. Objectives and criteria often vary between the operations phase and the closure phase with the closure phase being more stringent. They may also vary for each operations phase depending on the hazards and the duration of the phase. Closure objectives are particularly important in the initial planning for HLFs and are addressed in Section 5.7.

Some common types of design criteria for a HLF are identified below. The extent to which several of these analyses need to be performed is further described in Table 5-2.

- Ore mass scheduling must be reconciled to the stacking plans and geometric configurations of the HLF.
- Stability analysis must be done for the foundation materials underlying the HLF, the interfaces between the foundation material and the liner systems, the liner system interfaces and the interface between the upper liners and the overlying stacked material, the facility at full capacity of leached ore, and for any intermediate stacked configurations that result in potentially less stable configuration than the final stacked height. These analyses must include both static and seismic loading conditions and clearly indicate moisture conditions and the phreatic surface, both in the ore and rinsed residue, correlated against actual data.
- Foundation settlement and differential settlement analyses must be conducted for HLPs at full capacity and for any intermediate stacked configurations that result in potentially larger differential settlements than the final stacked configuration. The designs for the liner and heap drainage systems will need to accommodate the resulting strains in the liner systems and the changes in slope that occur on the drainage systems located on the liner systems.
- If frozen soils are present, thermal analysis must be conducted to assess the extent to which the frozen ground will thaw and the changes in the geotechnical properties of the soils resulting from any thawing must be considered in the foundation stability and settlement analyses.
- Liner system design calculations must be done to demonstrate that leakage rates will not cause any groundwater impacts above applicable water quality goals. These calculations must take into account the most reasonable number of imperfections in geomembranes for the level of construction quality assurance proposed, based on current practice and literature, and seepage rates through compacted underlying. Hydraulic heads on liners located immediately below stacked ore shall be based on the expected moisture conditions during leaching but in no event shall be assumed to be less than one metre.
- Overall water balance calculations must be done to determine what make-up water supplies are required, excess water discharge requirements, and what

pond storages should be provided for various stages of the HLF, including any proposed separate residue disposal facilities. These calculations must consider the water volumes stored in the heap under leaching conditions and in the solution collection and emergency overflow ponds. Determination of the amount of void space in a heap available for solution storage should consider the normal load from the maximum ore height in the ponds. Estimates of the amount of solution drain-down in a heap that occurs when leaching ceases should be based on appropriate laboratory testing.

- Water quality modelling must be done to assess the impacts on the quality of the receiving streams. These analyses must include expected and conservative assumptions for wet and dry conditions. Sensitivity analysis shall also be performed to determine the robustness of the predicted receiving water quality.
- Hydrologic calculations must be done to assess the design flood volumes and flood peaks to be conveyed in the diversions around the HLF and the solution channels and other conveyances within the HLF, and to be temporarily stored in the solution collection and emergency overflow ponds.
- Material balances must be done for the life of the HLF, demonstrating sufficient materials are available for the construction, operation and closure of the HLF.
- Analyses must be done demonstrating the HLF design will accommodate the closure grading requirements. An important consideration is to demonstrate how closure grading, if any, of the heap will be contained within the footprint of the lined area, or how the liner could be extended if necessary to beyond the operational footprint of the heap.

In addition to meeting the requirements and criteria specified in Table 5-2, the design, construction, operation and closure of HLFs must also comply with Chapter 13 of the *Plan Requirement Guideline for Quartz Mining Projects* (Yukon Government, 2013).

Table 5-2 *Minimum design criteria for heap leach facilities*

TABLE 5-2: MINIMUM DESIGN CRITERIA FOR HEAP LEACH FACILITIES			
CATEGORY	CLASS I	CLASS II	CLASS III
DESIGN EVENTS (HEAP, AND SOLUTION AND EVENT PONDS)[15] **Development, operations and closure phases**	**For heap leach facilities with in-heap storage ponds, see Table 4-2 for embankment design criteria. These facilities are treated as tailings storage facilities.**		
	Design earthquake for heap: Operations: 475 AEP Closure: same as operations	**Design earthquake for heap:** Operations: AEP Earthquake 2,475 – year Closure: same as operations unless long-term performance of the liner system is required to manage seepage from the facility, in which case the design even is the MCE.	**Design earthquake for heap:** Operations: AEP Earthquake 10,000 – year MCE Closure: same as operations
	Flood routing[16] Spillway is required IDF for Operations: 1/3 between the 1/975 and PMF for the critical duration event[17] IDF for Closure: same as operations	**Flood routing** Spillway is required IDF for Operations: 1/3 between 1,000-year and PMF for the critical duration event IDF for Closure: 2/3 between the 1/1,000yr and PMF for the critical duration event	**Flood routing** Spillway is required IDF for Operations: PMF for the critical duration event IDF for Closure: same as operations
	Catchment area for determining IDF: Catchment area for HLF component plus the catchment areas of the surface water diversions in the event the surface water diversions are designed to a smaller design flood than the spillway for the HLF component.		
	FLUID SYSTEM STORAGE CAPACITY REQUIREMENTS The sum of the following: • Normal maximum seasonal operating volume • 2 days of heap drain-down • 24h-100yr wet period including snowmelt • In addition, redundant pumps, pipelines and standby power are required as described in Section 5.5.	FLUID SYSTEM STORAGE CAPACITY REQUIREMENTS The sum of the following: • Normal maximum seasonal operating volume • 3 days of heap drain-down • 24h-500yr wet period including snowmelt • In addition, redundant pumps, pipelines and standby power are required as described in Section 5.5.	FLUID SYSTEM STORAGE CAPACITY REQUIREMENTS The sum of the following: • Normal maximum seasonal operating volume • 5 days of heap drain-down • 24h-1,000yr wet period including snowmelt • In addition, redundant pumps, pipelines and standby power are required as described in Section 5.5.
DESIGN METHODS AND FACTORS OF SAFETY FOR HEAPS **Development, operations and closure phases** **(Note that valley leach embankments and pond embankments are subject**	DESIGN METHODS • Average shear strength properties including interface friction angles • Upper bound phreatic surfaces • Limit equilibrium methods of stability calculations • Pseudo-static calculations for earthquake design including deformation analyses	DESIGN METHODS As for Class I plus • Lower bound shear strength properties	DESIGN METHODS As for Class II plus • For stability and deformation analyses, perform finite element or difference static and time-domain earthquake deformation analyses using the average geomechanical properties including undrained and residual shear strength, modules and modules degradation curves can be used.

[15] Heap leach facilities can include a series of ponds with spillways allowing flood waters to pass from one to the next. Designing for flood capacity should consider these as one interconnected system.
[16] Routine use ponds are ponds that are predicted to be used to store excess leaching solutions or heap runoff at least once annually under average climatic conditions.
[17] Critical duration may vary for a given facility depending upon whether the critical factor is management of peak flow or peak volume.

Table 5-2: Minimum Design Criteria for Heap Leach Facilities			
Category	**Class I**	**Class II**	**Class III**
to the Table 3-2 requirements)	**HEAP FACTORS OF SAFETY** **Slope stability** <u>Static:</u> Operations: FOS greater than 1.3 Closure: FOS greater than 1.5 <u>Seismic:</u> Pseudo-static - 1.0	**HEAP FACTORS OF SAFETY** **Slope stability** <u>Static:</u> Operations: FOS greater than 1.3 for slopes internal to heap and FOS greater than 1.5 for external slopes Closure: FOS greater than 1.5 <u>Seismic:</u> Pseudo-static - 1.0	**HEAP FACTORS OF SAFETY** **Slope stability** <u>Static:</u> Operations: FOS greater than 1.5 Closure: FOS greater than 1.5 <u>Seismic:</u> Pseudo-static - 1.0
LINER SYSTEMS CONSTRUCTION	**HEAP LEACH PAD – Portions with maximum hydraulic head < 1 metre** Protective granular layer overlying the liner Geomembrane liner with an underlying low hydraulic conductivity soil or geosynthetic clay liner. Design must be shown to be stable assuming these underlying layers are saturated considering both static stability and post-earthquake conditions with residual strengths.	**HEAP LEACH PAD – Portions with maximum hydraulic head < 1 metre** As for Class I plus Interface shear strength and puncture resistance testing with the anticipated loading and site-specific materials is required to demonstrate adequate liner strength and thickness. Granular materials strength properties must be lower bound and based on at least 3 shear tests using representative samples representing the range of material properties.	**HEAP LEACH PAD – Portions with maximum hydraulic head < 1 metre** As for Class II
	HEAP LEACH PAD – Portions with head 1 m or more Double geomembrane liner with leak detection and recovery system below the upper liner. Lower liner shall include a geomembrane liner with an underlying low hydraulic conductivity soil or geosynthetic liner. Design requirements as for the < 1 metre case above.		
	ROUTINE USE PONDS Double geomembrane liner with leak detection and recovery system below the upper liner. Lower liner shall include a geomembrane liner with an underlying low hydraulic conductivity soil liner or GCL. Leak detection system needs to be continuously dewatered. In the event this becomes impractical, the upper geomembrane liner leaks need to be repaired to reduce leakage to a rate that allows the leak detection system to be dewatered.		
	NON-ROUTINE USE PONDS Geomembrane liner with an underlying low hydraulic conductivity soil liner or GCL		
PERMAFROST CONSIDERATIONS **Development and operations phase**	**FIELD DATA COLLECTION REQUIREMENTS** Identify presence and characteristics of permafrost in accordance with NRC guidelines and Appendix B.	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 15 m depth, and ground ice content classification as per NRC guidelines	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 20 m depth and ground ice content classification as per NRC guidelines.

Table 5-2: Minimum Design Criteria for Heap Leach Facilities			
Category	Class I	Class II	Class III
			DESIGN REQUIREMENTS Design to include: • Settlement of thawed permafrost, due to both thawing of ground ice and long-term consolidation • Un-drained failure of thawed fine grained permafrost • Potential creep of ice-rich permafrost under load • Two-dimensional thermal analysis • Include climate change effects.
WATER MANAGEMENT **Development, operations and closure phases**	**SURFACE WATER DIVERSIONS** IDF for operations: 200 yr. IDF for closure: same as operations	**SURFACE WATER DIVERSIONS** IDF for operations: 200 yr. IDF for closure: 500 yr.	**SURFACE WATER DIVERSIONS** IDF for operations: 500 yr. IDF for closure: 1,000 yr.

5.3.3. Guidance for site and method selection

As indicated in Table 3-1, an options assessment is required as part of planning for management of a HLF. The options assessment is the basis for the selection of the sites for conducting the heap leach operations. The identification of HLF sites should begin with consideration of a broad range of options for stacking ore in one or more pads, at different locations and consideration of valley leach options as well. Detailed information on how to conduct an options assessments are presented in Appendix D.

5.3.4. Site characterization

Designs for HLFs should include site characterization that meets the requirements defined in Appendix B. The level of detail of the site characterization will increase as the level of design increases, with additional effort undertaken to collect more site-specific data as the design progresses.

For earlier levels of design, where site-specific data are less comprehensive, site characterization should be based on conservative assumptions about conditions, particularly the extent or presence of adverse conditions. Where potentially adverse conditions may fundamentally impact the feasibility of the proposed design, more advanced site characterization may be required to support early level designs.

For all stages of design, characterization of environmental and site conditions must be completed in sufficient detail to support the prediction of potential effects arising from construction, operation and closure of the HLF, and completion of any modelling and analyses for the design of the HLF and each of its components.

For geotechnical site characterization of foundations, site investigations must, at a minimum, conform to the site investigation guidelines issued by the Association of Professional Engineers and Geoscientists of British Columbia.

5.3.5. Facility design

The design of HLFs must be carried out by qualified professional engineers and environmental scientists. The overall design usually involves several different disciplines of engineering, geoscience and environmental scientists. As such, the design is normally carried out by a team of qualified professionals who are responsible for completing the design and producing the technical specifications, drawings and management plans.

Table C-1 in Appendix C provides guidance for the design process as it is refined over time; it is iterative and the design basis document is updated throughout the design process.

Design documents should also identify further design requirements, including additional levels of design and any management plans required to ensure construction and operation will comply with the objectives, assumptions and constraints.

Where leached ore is transported from the HLP to a separate facility for disposal, the design of that facility shall be treated as a MRMF. Lining the leached ore disposal facility will likely be necessary without considerable treatment of the residual ore prior to its removal from the HLP.

Designs for HLPs must consider the area required to stack the maximum amount of ore to be mined for leaching and for permanent closure. General considerations include the extent of grading and foundation preparation that needs to be completed to support a suitable liner system and the stacked ore, and access for trucks or conveyors to transport the ore onto the pad. Designs also need to include information on the ore lift heights, inter-bench slopes, overall heap slopes and bench widths to provide for effective ore stacking (and unstacking if necessary), leaching as well as short-term stability during operational leaching and long-term stability during the post-closure period. Other considerations include the suitability of the ore for conducting leach solutions without clogging or extensive saturation zones developing that could result in inefficient rinsing or excess pore pressure buildup potentially leading to HLP slope failures and creating liquefaction risk.

Further considerations include the drainage of surface runoff around the proposed leach pad area or areas, drainage of leachate from the liner systems and solution conveyance pipelines and ditching around the perimeter of the leach pad to the solution collection ponds and tanks, drainage of surface water runoff and snowmelt from the surface of the heap into the solution collection pond or ponds, and an emergency storage pond or ponds for extreme runoff and precipitation volumes. In some instances the proponent may propose internal berm off cells within the HLP footprint to facilitate collection of leachate solution from different segments of the HLP and during closure, allow selective rinsing of segments to occur once leaching is completed and prior to completion to leaching of all segments. Use of such cell construction is encouraged as it allows for concurrent reclamation.

5.3.6. Risk assessment

The design for the HLF and its components must include systematic risk assessment approaches to characterize risks that the HLF will not perform as expected. The purpose of the risk assessment is to evaluate the risks, modify design approaches and develop mitigation measures that minimize the risks to an acceptable level, and characterize immitigable residual risks.

The level of effort for risk assessment will vary depending on the severity of hazards associated with each HLF, but in all cases, the HLF design must consider and address the results of a risk assessment using methodologies described in Appendix E. This includes the implementation of additional risk assessment methodologies as appropriate for each class of HLF. The risk assessment process completed in accordance with Appendix E must be facilitated by an experienced risk assessment professional and include full participation of both the proponent's experts and representatives of interested parties, such as regulators and First Nations.

Risk assessments should be completed incrementally as the design level evolves; however, a comprehensive assessment should be completed in association with the feasibility design.

5.4. Guidance for construction

5.4.1. Construction plan

A construction plan for describing the construction management and supervision, sequence/schedule, temporary facilities, environmental management, quality assurance/quality control, emergency management, change management and requirements for commencing operations must be prepared and submitted with regulatory applications. The role of the EOR must be clearly defined through all stages of construction.

Detailed requirements for construction plans are described in Appendix F.

5.4.2. As-built report

As-built reports must be provided upon completion of construction of a heap leach facility, and for each modification or expansion of the pad or any of its retaining, containment or conveyance components. Each as-built report must be certified by the EOR and must contain:

- A complete set of drawings depicting the as-built condition of all components of the heap leach facility.
- Results of the construction QA/QC programs including results of inspections and testing. Identify any non-compliant test results and describe how these were addressed.
- Description of issues or concerns encountered during construction.
- Records of changes implemented during construction, including approvals by the EOR for the changes.
- Any recommendations from the EOR relating to operations, maintenance and surveillance for the HLF.
- Statement by the EOR that the HLF was constructed per design.

5.5. Guidance for operations

5.5.1. System redundancies

Once operating, large volumes of solution are continually circulated using pumps and pipelines in addition to a large solution inventory in the heap itself, referred to as "dynamic storage." This storage generates a solution flow onto the liner that has to be continually collected and returned to the process facility. When solution application to the surface stops, there remains a lagging solution inventory drain-down that will continue to require collection. The solution ponds provided for the temporary storage of the drain-down, but must be large enough to accommodate the drain-down for an appropriate period of time in addition to the water that accumulates on the HLF during extreme precipitation and snowmelt events. To appropriately manage solution and prevent a potential release to the environment, it is necessary that the ponds are sized sufficiently and that there is also redundant piping, pump capacity and emergency power at the site to allow solution to be transferred in the event there is a power outage and a significant freeze-up of the operating pipelines.

Operators are therefore required to provide sufficient redundant pumps, piping and other associated equipment on site to be able to restore the capacity to manage leach solutions in an emergency event. It is also necessary to provide for standby power to operate the pumps with sufficient fuel for at least 2-weeks of operation. The required pond sizes are contained in Table 5-2.

5.5.2. Operations, maintenance and surveillance

All facilities must have an operation, maintenance and surveillance manual (OMS manual) that describes the operational actions and approaches that will be in place to ensure compliance with the HLF design. It should also describe the provisions for back-up power, the redundancies in piping and pumping capacity provided, and how solution will be managed in the event of a power failure and major pump and pipeline freeze-up. Operational decisions about water management, solution control and containment must be guided by the OMS manual, which must clearly define the overall responsibility of a corporate executive in charge of HLF management, and the ongoing role of the EOR throughout operations.

The main sections of an OMS manual will usually include roles and responsibilities, facility description, operation, solution management, maintenance, surveillance and emergency planning and response.

The OMS manual should identify site-specific issues of importance, including the trigger levels for instrumentation. The OMS manual must be updated on a regular basis and copies provided to regulatory agencies.

OMS manuals must be consistent with *Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities* (Mining Association of Canada, 2021). The HLF OMS manual must also include the audit protocol that will be used for required reviews.

5.5.3. Environmental monitoring and reporting plan

Environmental monitoring and reporting for the operational phase of the HLF must be addressed in an overall environmental monitoring plan for the complete project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

For projects that include HLFs, monitoring programs need to include data to support the following during the operations phase:

- Annual ore as-built stacking plans including the status of any concurrent or progressive rinsing, reclamation or closure;
- Development, calibration and refinement of water balance model and contaminant load model;
- Evaluation of solution inventories, water balance and contaminant loading outcomes;
- Leak detection monitoring and response;
- Evaluation of any contaminant-related effects in the aquatic, terrestrial or atmospheric environment; and
- Evaluation of any physical effects on wildlife or wildlife habitat.

5.6. Guidance for closure

5.6.1. Introduction

As described in Section 3.2, planning for closure of a HLF must be conducted in parallel with initial design of selected management option, applying the design-for-closure concept.

The closure plan for a HLF must meet the general requirements in the *Yukon Closure Guide* and *Yukon Closure Policy*, and be part of the integrated site reclamation and closure plan (RCP). The RCP must address all closure types and phases of the project including temporary closure, progressive reclamation during operations, interim care-and-maintenance, active closure and post-closure. It must also contain clear objectives for each closure phase, which become more clearly defined as operations and trials advance to meet measurable objectives and criteria in line with end land-use objectives.

A RCP needs to be adaptable to changes in the construction and operation, and refined throughout the life of the HLF. Updates should include any changes and refinements to proposed closure measures. They should also present designs at increasing levels of detail as the development of the HLF progresses so that detail sufficient for construction is available before closure implementation.

Closure plans submitted to support environmental assessment and permitting processes must clearly describe practical and feasible approaches for achieving the defined closure objectives. Options for closure of the HLF and its components should be evaluated as part of the initial selections of the heap leach management method and site, as described in Section 5.3.3.

Immediately prior to closure, the performance of any liner system used must be assessed as part of the inspections and reviews required in accordance with Table 3-3. In the event these inspections and reviews conclude the performance is inadequate, corrective measures need to be designed and installed. Corrective measures could include, but are not limited to, seepage collection systems and low-permeability soil or geomembrane covers.

At closure, heap leach slopes, inclusive of inter-bench slopes, must be reduced to at least 3 (horizontal) to 1 (vertical). Proponents are encouraged to use landform engineering when regrading the HLF for closure. Application of a cover system to reduce net percolation is required for all HLFs.

Environmental monitoring and reporting for the active closure phase of HLFs must be addressed in an overall environmental monitoring plan for the complete active closure project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program. Monitoring during closure will be a continuation of the operational monitoring program with refinements to address the changes in the types of activities that will be occurring and any changes in solution management. Water balance, contaminant loading, solution management and inventory, leak detection and response, effects on wildlife and wildlife habitat will continue to be important monitoring issues for HLFs during the closure phase.

5.6.2. Risk assessment

The designs for closure of the HLF and its components must include systematic risk assessment approaches to characterize risks that the RCP will not achieve the closure objectives and criteria. The initial closure plan for the HLF must consider and address the results of a risk assessment using methodologies described in Appendix E. As the closure objectives and design progress, the risk assessment should be repeated to incorporate any changes in the mine plan and HLF design, and to confirm that, where possible, the risks identified in early risk assessments are being reduced by the refined RCP. For outstanding risks, the RCP should describe contingency and emergency response measures.

5.7. Guidance for post-closure

The closure plan for a HLF must describe the activities and requirements for the post-closure stage. The RCP should clearly define the duration of the post-closure stage. The post-closure stage continues until the site has achieved self-sustaining, long-term stable conditions comparable to surrounding terrain, without human intervention. HLFs that require ongoing monitoring and maintenance of water retaining and conveyance structures must consider very long duration post-closure stages.

5.7.1. Maintenance and surveillance

Each HLF closure plan should be accompanied by a maintenance and surveillance plan for the post-closure period. The plan should describe what activities would be undertaken to ensure the conditions continue to achieve closure objectives and criteria. At a minimum, the post-closure maintenance and surveillance plan should address the following aspects:

- Site security;
- HLF inspections;
- Operations of water management systems including rinsing, detoxification if applicable, and any leachate collection, treatment and discharge systems;
- Water quality discharge and receiving water standards;
- Identification of potential risks;
- Contingency and emergency response plans;
- Access to HLF areas potentially requiring future maintenance;

- Power supply;
- Maintenance crew and equipment;
- Routine maintenance of mechanical water management systems;
- Routine inspections and maintenance of any access roads, dams and HLF covers, including erosion repairs and vegetation maintenance; and
- Inspections and non-routine maintenance after severe storm events, for example.

5.7.2. Monitoring and reporting

Long-term water quality, contaminant loading and effects on wildlife and wildlife habitat will continue to be important monitoring issues for HLFs during the post-closure phase. Environmental monitoring and reporting for the post-closure stage of any HLF must be addressed in an overall environmental monitoring plan for the complete post-closure project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

Assuming that the effluent from HLPs can be easily managed and drained as part of active closure, post-closure monitoring requirements may be reduced in recognition of the diminished potential for environmental effects. However, post-closure monitoring for HLFs must continue to provide information about water quality, contaminant loading and migration. It should also address wildlife and wildlife habitat to demonstrate that reclamation objectives are achieved.

Post-closure monitoring of HLFs must continue for as long as the facilities present any physical or chemical risk.

6. Mine rock management facilities

6.1. Introduction

This chapter provides guidance for mine rock management facilities. Mine rock management facilities (MRMFs) include mine rock storage piles containing the un-mineralized and uneconomic rock excavated from the mine that is permanently stored on the surface, as well as ore, low-grade ore and overburden stockpiles, which can either be temporary, until the ore is processed, or permanent in the event the mine ceases operations before the ore is processed.

In some cases, mine rock will be stockpiled in a mined out pit or behind an impoundment. Typically, this is done to provide a permanent water cover over the mine rock in order to suppress geochemical reactions, which could lead to water quality impairment in the long term. This type of storage can also be used to partially return the land to its pre-mining topography, stabilize slopes, reduce the total disturbance area or for economic reasons.

Initial planning for MRMFs must follow a design-for-closure approach to demonstrate how the facilities will meet the relevant criteria for all project phases and achieve suitable long-term performance.

The Yukon Plan Guide, especially Chapter 15, provides guidance about the content of MRMF designs. The guidance provided in that document complements the guidance and standards provided in this chapter, which should be incorporated into any mine rock and overburden management plan.

Physical stability of MRMFs must be considered for two key periods, when the factors affecting performance are different:

- During construction, which occurs throughout the mine operating phase. Designs and construction methods are required to prevent any surficial or deep-seated failures of the piles as they are constructed and to control erosion for the surfaces of the piles. Since the piles are continually being constructed during the mine's operating phase, rock placement plans are required to ensure the established design criteria are being met at all times.

- After closure, which includes providing for stable slopes, and a durable surface, which provides for erosion protection in the long term. Closure stability can be enhanced by re-grading the piles after initial placement and providing earthen covers that support vegetation and reduce infiltration of rain and snowmelt.

Mine rock can generally range from chemically inert to chemically reactive, and can include a combination of both types. The movement of chemically inert materials has no different impact on water resources than if the material is left in place. For these materials, concerns are usually limited to the prevention of excessive erosion and sedimentation.

Chemically reactive rocks contain minerals that are subject to oxidation in the presence of water and oxygen and which can impart dissolved metals and salts to contact water. These materials must be managed to avoid unacceptable effects of contaminant loading in the environment.

Residuals from the explosives used in mining can impart nitrate and ammonia to any water that comes into contact with the MRMF materials. Dissolved nitrate and ammonia can be an issue during both operations and closure phases as they are flushed out of MRMFs.

These controls are required for MRMFs to prevent the materials from causing unacceptable ground- and surface-water quality impacts:

- Erosion control during construction. Designs, construction and operational methods and plans are required to prevent and manage sediment and turbidity impacts to surface waters adjacent to the MRMFs and meet established water quality standards and objectives.

- Surface and groundwater management during the mine operating phase to prevent impacts to ground or surface water from nitrates, metal leaching (ML) and acid rock drainage (ARD).
- Surface and groundwater management after closure, which includes providing suitable covers that minimize effects from sediment and, if necessary, ML/ARD. Covers should also support the development of stable, self-sustaining vegetation.

It is important to recognize that the geochemical oxidation processes can sometimes occur very slowly, and mine rock that is initially benign can develop significant ML/ARD over a period of years or even decades. Careful interpretation of laboratory tests undertaken to establish the ML/ARD potential is therefore essential, as is monitoring of the runoff and leachate quality from piles during their construction. Monitoring programs need to be able to detect subtle chemical changes in water quality over time.

6.2. Facility classification

The health and safety, environmental, cultural and other hazards associated with MRMFs will vary depending on a range of factors including size, location, material physical and geochemical properties, and in some cases community resilience. Requirements for design, construction, operation and closure can help to reduce risks from MRMFs. Reducing risks to acceptable levels requires application of more stringent requirements for projects that have higher hazard than for those with lower hazard.

In the context of the classifying MRMFs, the boundaries between classes should not be interpreted as being definitive; numerical values associated with defining the classes are to be interpreted as indicative values only. Judgement and a holistic approach should be used where MRMFs are proposed to have characteristics near the boundaries of classes.

Proponents are required to define the facility classification for any proposed MRMF in accordance with the criteria and thresholds provided in Table 6-1. In classifying MRMFs, it should be recognized that the hazard and consequence of failure of a MRMF may not be constant through its life phases. While MRMFs are generally expected to represent a peak hazard level at their full build-out, the classification process must examine all phases and stages to determine the critical phase and stage for classification purposes.

Table 6-1 *Mine rock management facility classification*

TABLE 6-1: MINE ROCK MANAGEMENT FACILITY CLASSIFICATION			
FACILITY CHARACTERISTICS	FACILITY CLASS		
CHARACTERISTIC	CLASS I	CLASS II	CLASS III
Maximum height above natural ground[18]	Less than 50 metres, or waste rock that is geologically contained.[19]	Between 50 and 200 metres.	More than 200 metres.
Presence of permafrost	No permafrost present under critical elements of the facility.	Permafrost present and ice-rich permafrost removed to thaw stable materials under critical elements of the facility.	Ice-rich permafrost present and not fully removed under critical elements of the facility.
Geochemistry of waste rock	Only NAG waste present.	PAG waste present, but not placed in any potential water flow path (e.g., stream, runoff or groundwater seepage path)[20].	PAG waste placed in potential water flow path.
Predicted water quality of waste rock runoff or seepage (at time of most adverse predicted water quality)	Surface runoff and seepage from facility predicted to have contaminant concentrations – exclusive of total suspended solids (TSS) – that are less than 10x applicable receiving water quality guidelines or site-specific water quality objectives for all contaminants of concern (COCs).	Surface runoff or seepage from facility predicted to have concentrations for one or more COC – exclusive of TSS – that is between 10x and 500x applicable receiving water quality guidelines or site-specific water quality objectives.	Surface runoff or seepage from facility predicted to have concentrations for one or more COC – exclusive of TSS – that is greater than 500x applicable receiving water quality guidelines or site-specific water quality objectives.
Runoff or leachate management requirements	Protection of receiving water does not require active or passive management of water discharges other than sediments controls during the operations phase.	Protection of receiving water requires: (a) active or passive management of water discharges during the operations, care and maintenance and active closure stages; or (b) passive management of water discharges during the post-closure stage.	Protection of receiving water requires active management of water discharges during the post-closure stage.
Surface water conditions	MRMF not located on stream channels, or located on steam channels with catchment areas <1 km^2 (area calculated at the upstream edge of the MRMF).	MRMF located on steam channels with a total catchment area upstream of the MRMF of between 1 and 10 km^2.	MRMF located on steam channels with a total catchment area upstream of the WRMF > 10 km^2.
Human health and safety	Other than the temporary presence of mine workers carrying out their duties, there is no identifiable population at risk from a failure of the facility.	People, other than mine workers carrying out their duties, are only temporarily in the failure hazard zone for the facility (e.g., seasonal use, passing through on transportation routes, recreational activities).	People (including mine workers) permanently live or work in the failure hazard zone.
Facility closure costs[21]	Less than 10 million dollars	Between 10 million and 50 million dollars	More than 50 million dollars

[18] Measured as the maximum vertical depth of waste rock above natural ground.
[19] "Geologically contained" refers to storage of waste rock in pits or other geologically contained areas, where all waste rock is stored below the lowest elevation of the rim of the containment.
[20] For the purposes of evaluating this criterion, meteoric water infiltration through waste rock pile is not considered a water flow path.
[21] If a mine operation includes more than one MRMF, the closure cost is defined as the total closure cost for all MRMFs.

6.3. Guidance for planning and design

6.3.1. Introduction

The phases of design for a MRMF include the initial construction for preparing the MRMF area and associated groundwater protection and surface water management facilities, designs for the staged expansion during the operating period, plans which describe how the materials are to be stacked over time, the closure activities which can include selective grading and cover placement, revegetation as necessary, and the long-term water management and maintenance.

At all levels of design, the designs should all incorporate “design for closure” principles and therefore the initial design, the closure option selection and conceptual closure designs should be done in parallel.

A specific issue in the Yukon is the effect of cold temperatures on the operation and maintenance of MRMFs including appurtenant structures and facilities. Experience with cold regions’ issues is critical to ensure appropriate planning and design for MRMFs. In addition to the consideration of current climatic conditions, it is critical that MRMFs are planned, designed, built and operated to withstand projected impacts of climate change.

Further guidance for conducting designs is provided in Appendix C.

6.3.2. Design objectives, requirements and criteria

The designs must comply with the minimum requirements for each hazard classification as described in Table 6-2. Where MRMFs present hazards that fall within the upper range of a specific classification, the minimum requirements for that class may not be sufficient.

In addition to meeting the requirements and criteria specified in Table 5-2, the design, construction, operation, and closure of MRMFs must also comply with Chapter 15 of the *Plan Requirement Guideline for Quartz Mining Projects* (Government of Yukon 2013).

Table 6-2 *Minimum Design Criteria for Mine Rock Management Facilities*

TABLE 6-2: MINIMUM DESIGN CRITERIA FOR MINE ROCK MANAGEMENT FACILITIES[22]			
CATEGORY	**CLASS I**	**CLASS II**	**CLASS III**
DESIGN EVENTS **Construction, operations and closure**	**Seismic design of rock piles** Operations: 200 yr. EDGM Closure: same as operations	**Seismic design of rock piles** Operations: 500 yr. EDGM Closure: same as operations	**Seismic design of rock piles** Operations: 1,000 yr. EDGM Closure: same as operations
	DESIGN FLOOD:[23] **Surface water diversions and conveyance systems** Design flood (DF) for operations: 200yr AEP DF for closure: same as operations	**DESIGN FLOOD:** **Surface water diversions and conveyance systems:** DF for operations: 200yr DF for closure: 500yr (If a demonstration can be made that failure of the diversions would not lead to release of waste rock or environmental impacts more significant than those experienced in natural terrain during extreme storm events, a lower design flood can be proposed)	**DESIGN FLOOD:** **Surface water diversions and conveyance systems:** DF for operations: 500yr DF for closure: 1,000yr (If a demonstration can be made that failure of the diversions would not lead to release of waste rock or environmental impacts more significant than those experienced in natural terrain during extreme storm events, a lower design flood can be proposed)
DESIGN METHODS AND FACTORS OF SAFETY (Note that pond embankments are subject to the Table 3-2 requirements)	**DESIGN METHODS FOR MINE ROCK PILE** Average shear strength properties Expected phreatic surfaces Limit equilibrium methods of stability calculations Pseudo-static calculations for earthquake design	**DESIGN METHODS FOR MINE ROCK PILE** As per Class I	**DESIGN METHODS FOR MINE ROCK PILE** Reasonably conservative shear strength properties and phreatic surfaces Limit equilibrium methods of stability calculations Pseudo-static calculations for earthquake design Seismic deformation analyses
	ROCK PILE FACTORS OF SAFETY **During operations:** Static: greater than 1.3 Pseudo-static: greater than 1.0 **During closure and post-closure:** Static: greater than 1.3 Pseudo-static: greater than 1.0 Post-earthquake: greater than 1.1	ROCK PILE FACTORS OF SAFETY **During operations:** Static: greater than 1.3 Pseudo-static: greater than 1.0 **During closure and post-closure:** Static: Greater than 1.5 Pseudo-static: greater than 1.0 Post-earthquake: greater than 1.2	ROCK PILE FACTORS OF SAFETY **During operations:** Static: greater than 1.5 Pseudo-static: greater than 1.0 Deformation analyses: Predicted seismic deformations should not result in any risks to human safety, cause damage to any infrastructure, or result in a major release of waste or ore that causes significant environmental damage **During closure and post-closure:** Static: Greater than 1.5 Pseudo-static: greater than 1.0 Post-earthquake: greater than 1.2

[22] This applies to free-draining non-impounding waste rock facilities. If impoundment is required for water management purposes, the design approach is as per TMF table 4-2
[23] Design criteria for seepage collection ponds, if required, will be based upon site-specific factors, including seepage water quality and volume.

Table 6-2: Minimum Design Criteria for Mine Rock Management Facilities[22]			
Category	**Class I**	**Class II**	**Class III**
			Deformation analyses: Predicted deformations should not result in displacement of any waste material outside of the designated footprint area of the closed and reclaimed WRMF.
PERMAFROST CONSIDERATIONS	**FIELD DATA COLLECTION REQUIREMENTS** Identify presence and characteristics of permafrost in accordance with NRC guidelines and Appendix B	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 15 m depth, and ground ice content classification as per NRC guidelines	**FIELD DATA COLLECTION REQUIREMENTS** Presence and characteristics of permafrost – stabilized ground temperature profile to at least 20 m depth and ground ice content classification as per NRC guidelines.
			DESIGN REQUIREMENTS Design to include: • Settlement of thawed permafrost, due to both thawing of ground ice and long-term consolidation • Undrained failure of thawed fine grained permafrost • Potential creep of ice-rich permafrost under load • Two-dimensional thermal analysis • Include climate change effects.
ROCK DRAINS	Design for the 100-year rainfall or snowmelt event. Design factor of safety: 5 Demonstrate durability of drain rock for the operating phase considering both physical and geochemical deterioration that can occur.	Design for the 100-year rainfall or snowmelt event. Design factor of safety: 5 Demonstrate long-term durability of drain rock considering both physical and geochemical deterioration.	Design for the 200-year rainfall or snowmelt event Design factor of safety: 10 For closure: Demonstrate long-term durability of drain rock considering both physical and geochemical deterioration.
SURFACE WATER MANAGEMENT	**WATER QUALITY POND CAPACITY** **EDF:** • Spillway is required • Mine-site wide water balance analyses to demonstrate accumulated water can be recycled or treated and discharged.	**WATER QUALITY POND CAPACITY** **EDF:** • Spillway is required • Mine-site wide water balance analyses to demonstrate accumulated water can be recycled or treated and discharged. Where treatment is required, see Table 2-1 for Class II	**WATER QUALITY POND CAPACITY** EDF: • Spillway is required • Mine-site wide water balance analyses to demonstrate accumulated water can be recycled or treated and discharged. Where treatment is required, see Table 2-1 for Class III

Table 6-2: Minimum Design Criteria for Mine Rock Management Facilities[22]			
Category	Class I	Class II	Class III
	Seepage collection pond flood routing This feature may not be present. Design as per Table 3-2 and based on corresponding hazard classification for the pond embankments provided in Table 3-1. **Catchment area for determining IDF:** Catchment area for the MRMF plus the catchment areas of the surface water diversions, in the event the surface water diversions are designed to a smaller design flood than the MRMF.		

6.3.3. Guidance for site and method selection

As indicated in Table 3-1, an options assessment is required as part of planning for management of mine rock. The options assessment is the basis for the selection of the sites and methods for managing mine rock. Detailed information on how to conduct options assessments is presented in Appendix D.

The location of a MRMF is generally determined by the location of the mine itself, and is influenced by the site topographical features, and space available for materials and the water management facilities, and in the case of ore and low-grade ore stockpiles, the location of the process plant. A dominant determining factor is the minimization of the haul distance between the mine and the location of mine rock piles.

The required site selection scope for the various types of MRMFs is as follows:

- **Mine rock storage piles:** These are typically the largest features and will require site selection studies and alternatives analysis for piles emanating from both open pit and underground mines as described below.
- **Low-grade ore stockpiles:** Low-grade ore stockpiles should be treated as for mine rock above, since they can involve significant volumes and may not be processed and require closure similar to mine rock piles. Often, low-grade ore stockpiles are contiguous to the mine rock material.
- **Ore stockpiles:** These are generally located within proximity of the ore preparation and processing facilities and are included in the layout and environmental assessment of those features. No specific site selection process is required.
- **Overburden stockpiles:** The locations of these are generally determined by the proximity to the source areas, sufficient storage area, and proximity to the final use areas; e.g., placement of closure covers. Closure requirements including ease of access and material re-use must be considered in any site selection process for overburden stockpiles.

Initially, all technically and economically feasible sites that are large enough for the proposed MRMFs must be identified and subjected to the options analysis and selection process described in Appendix D. The size and types of MRMFs selected should consider available area, topography, climate, foundation conditions, environmental, closure and geochemical properties.

6.3.4. Site characterization

To support the design for MRMFs, the selected sites must be characterized in accordance with Appendix B of this document and meet the minimum requirements described in Table 6-2 for the relevant facility classes.

For earlier levels of design, where site-specific data are less comprehensive, site characterization should be based on conservative assumptions about conditions, particularly the extent or presence of adverse conditions. Where potentially adverse conditions may fundamentally impact the feasibility of the proposed design, more advanced site characterization may be required to support early level designs.

For all stages of design, characterization of environmental and site conditions must be completed in sufficient detail to support the prediction of potential effects arising from construction, operation and closure of the MRMF, and completion of any modelling and analyses for the design of the MRMF and each of its components.

For geotechnical site characterization of foundations, site investigations must at least conform to the site investigation guidelines issued by the Association of Professional Engineers and Geoscientists of British Columbia.

6.3.5. Facility design

The design of MRMFs must be carried out by qualified professional engineers and qualified environmental professionals. The overall design usually involves several different disciplines of engineering, geoscience and environmental science. As such, the design is normally carried out by a team of qualified professionals who are responsible for completing the design and producing the technical specifications, drawings and management plans.

Table C-1 in Appendix C provides guidance for the design process as it is refined over time; it is iterative and the design basis document is updated throughout the design process.

Design documents should also identify further design requirements, including additional levels of design and any management plans required to ensure construction and operation will be in compliance with the objectives, assumptions and constraints.

Designs for MRMFs must consider the area required to stack the maximum amount of material to be stockpiled. General considerations include the extent of grading and foundation preparation that needs to be completed to support suitable under drains and liner systems if necessary. Designs must include information on the material lift heights, inter-bench slopes, overall pile slopes and bench widths to provide for effective material stacking (and unstacking if necessary for low-grade ore, for example), short-term stability during construction and long-term stability during the post-closure period. Other considerations include the potential for extensive saturation zones developing that could result in pore pressure buildup potentially leading to MRMF slope failures. Rock drains are required to convey infiltration and spring flow without the buildup of hydraulic head in the waste piles. Allowance should be made for infiltration, spring flows and any inflow into the pile from adjacent catchment areas. Note that infiltration rates will be highest during operations and lower after closure and reclamation.

Designs should also include water management plans that consider both clean and contact water. They should address, for example, the drainage of surface runoff around the proposed MRMF, drainage of leachate from the MRMF if proposed, ditching around the perimeter of the pile to the solution collection ponds and drainage of surface water runoff and snowmelt from the surface of the pile into the detention and water quality ponds.

Design of MRMFs must include analysis and supporting modelling to determine whether a liner system is required to address potentially unacceptably adverse water quality impacts in the receiving environment (including both surface water bodies and ground water aquifers). The need for liner systems should be based on fate and transport analyses and with the objective of preventing exceedances of applicable groundwater and surface water objectives outside the footprint of the MRMF. Fate and transport analyses should include reasonable assumptions for the following parameters and calculation methodologies:

- Hydraulic head on the foundation or liner system if proposed;
- If a lined containment is proposed, expected number and size of perforations in constructed geomembrane liner systems for the anticipated construction quality assurance;
- Upper bound hydraulic conductivity values for any natural clay or silt layers or liners proposed;[24]
- Seepage losses using established analytical formula or models.
- Upper bound hydraulic conductivity analyses based on field measurements for the unsaturated zone including measurement below the liner system, if proposed;
- Saturated or unsaturated seepage analyses between the foundation liner and the groundwater table; and
- Reasonable allowance for mixing of seepage and groundwater.

In the event the above analyses indicate that water quality objectives will or may be exceeded, then a liner system will be required or if proposed, the liner system will need to be improved by adding layers.

The above analyses may have to be repeated with different liner systems until a suitable system is selected. The latest literature should be consulted to estimate the amount of defects in a geomembrane liner in a mining application.

Generally, the following information on material characteristics is required for the design of a MRMF (see also Table 6-2 and Chapter 15 of the *Yukon Plan Guide*):

- General description of the particle size of the material to be stockpiled;
- Strength properties;
- Permeability measurements, saturated and unsaturated, to inform seepage modelling and determination of liner requirement;

[24] laboratory test results to be adjusted for expected "as built" field conditions

- The geochemistry of the material or various material types including its mineralogy, metal content, expected nitrate content, ARD and ML potential, and expected contaminant loading; and
- Categorization of the material or various material types as either PAG or NAG.

6.3.6. Risk assessment

The design for the MRMF and its components must include systematic risk assessment approaches to characterize risks that the MRMF will not perform as expected. The purpose of the risk assessment is to evaluate the risks, modify design approaches, develop mitigation measures and identify residual risks that cannot be mitigated.

The level of effort for risk assessment will vary depending on the class of MRMF and severity of hazards associated with each MRMF, but in all cases, the MRMF design must consider and address the results of a risk assessment using methodologies described in Appendix E. The risk assessment process completed in accordance with Appendix E must be facilitated by a well-experienced risk assessment professional, and include the participation of both the proponent's experts and representatives of interested parties.

Risk assessments should be completed incrementally as the design level evolves; however, a comprehensive assessment should be completed in association with the feasibility design.

6.4. Guidance for construction

6.4.1. Construction plan

Construction plans must be provided for the MRMF and for all contact water conveyance and storage systems, liners if provided, clean-water conveyance facilities and any other components that are part of a MRMF or required for its construction.

Construction plans must describe construction management and supervision, sequence/schedule, temporary facilities, environmental management, quality assurance/quality control, emergency management, change management, and requirements for commencing operations. The role of the EOR should be clearly defined through all stages of construction.

Detailed requirements for construction plans are described in Appendix F.

6.4.2. As-built report

As-built reports must be provided upon completion of the footprint preparation and construction of infrastructure for the MRMF, and for each modification or expansion of the MRMF or any of its drainage, conveyance or water collection components. Each as-built report must be certified by the EOR and must contain:

- A complete set of drawings depicting the as-built condition of all components of the MRMF.
- Results of the construction QA/QC programs including results of inspections and testing. Identify any non-compliant test results and describe how these were addressed.
- Description of issues or concerns encountered during construction.
- Records of changes implemented during construction, including approvals for the changes.
- Any recommendations from the EOR relating to operations, maintenance and surveillance for the MRMF.

6.5. Guidance for operations

6.5.1. Operations, maintenance and surveillance

All MRMFs must have an operation, maintenance and surveillance manual (OMS manual) that describes the operational actions and approaches that will be in place to ensure compliance with the MRMF design. Operational decisions about mine rock management, material segregation and water management must be guided by the OMS manual, which must clearly define the overall responsibility for decision-making about the operation and construction of the MRMF.

The main sections of an OMS manual will usually include roles and responsibilities, facility description, operation, maintenance, surveillance and emergency planning and response. s

The OMS manual should identify site-specific issues of importance, including the trigger levels for instrumentation. The manual must be updated on a regular basis and copies provided to regulatory agencies.

OMS manuals must be consistent with the practices in *Guidelines for Mine Waste Dump and Stockpile Design* (Hawley and Cunning, 2017).

6.5.2. Environmental monitoring and reporting

Environmental monitoring and reporting for the operational phase of the MRMF must be addressed in an overall environmental monitoring plan for the complete project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

For projects that include MRMFs, monitoring programs need to include data to support the following during the operations phase:

- Annual mine rock as-built stacking plans;
- Routine stability inspections and assessments;
- Tracking of contact water and leachate flow quantiles and chemistry, including dissolved metals, salts, pH and acidity;
- Effects if any on groundwater quality;
- Evaluation of any contaminant-related effects in the aquatic, terrestrial or atmospheric environment; and
- Evaluation of any physical effects on wildlife or wildlife habitat.

6.6. Guidance for closure

6.6.1. Introduction

As described in Section 3.2, planning for closure for a MRMF must be conducted in parallel with initial design of the MRMF, applying the design-for-closure concept.

The closure plan must meet the general requirements in the *Yukon Closure Guide*, and *Yukon Closure Policy*, and be part of the integrated site-wide RCP. The closure plan must address all phases of the project including temporary closure, progressive reclamation during operations, interim care-and-maintenance, active closure and post-closure.

The closure plan needs to be adaptable to changes in the construction and operation of the MRMF. RCP updates should include any changes and refinements to proposed closure measures. They should also present designs at increasing levels of detail as the development of the MRMF progresses so that detail sufficient for construction of all closure components is available before closure implementation. Where specific MRMFs are completed prior to completion of mining activities, progressive reclamation must be considered and completed where possible.

Closure plans submitted to support environmental assessment and permitting processes must clearly describe practical and feasible approaches for achieving the defined closure objectives.

At closure, MRMF slopes, inclusive of inter-bench slopes, must be reduced to at least 3 (horizontal) to 1 (vertical) or flatter, unless the proponent can demonstrate that alternative slopes meet closure objectives and that, by using landform engineering principles, they can demonstrate that the proposed slopes are stable in the long term. Proponents are encouraged to use landform engineering when regrading the MRMF for closure. Application of a cover system to reduce net percolation is required for all MRMFs unless a proponent can demonstrate that the MRMF contains only durable rock and that water infiltration will not affect the long-term chemical and physical stability of the facility.

Environmental monitoring and reporting for the active closure stage of MRMFs must be addressed in an overall environmental monitoring plan for the complete active closure project. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program. Monitoring during the closure phase will be a continuation of the operational monitoring program with refinements to address the changes in the types of activities that will be occurring. Water balance, contaminant loading, and effects on wildlife and wildlife habitat will continue to be important monitoring issues for MRMFs during the closure phase.

6.6.2. Risk assessment

The designs for closure of the MRMF and its components must include systematic risk assessment approaches to characterize risks that the closure plan will not achieve the closure objectives and criteria. The initial closure plan for the MRMF must consider and address the results of a risk assessment using methodologies described in Appendix E. As the closure plan and design progress, the risk assessment should be repeated to incorporate any changes in the mine plan and MRMF design, and to confirm that, where possible, the risks identified in early risk assessments are being reduced by the refined closure plan. For outstanding risks, the closure plan should describe contingency and emergency response measures.

6.7. Guidance for post-closure

The closure plan for a MRMF must describe the activities and requirements for the post-closure stage. The closure plan should clearly define the duration of the post-closure stage. The post-closure stage continues until the site has achieved self-sustaining, long-term stable conditions comparable to surrounding terrain, without human intervention.

6.7.1. Maintenance and surveillance

Each MRMF closure plan should address potential long-term maintenance requirements for the post-closure period. The plan should describe what activities would be undertaken to ensure the MRMF continues to achieve closure objectives and criteria. At a minimum, the post-closure maintenance and surveillance plan should address the following aspects:

- Site security;
- MRMF inspections;
- Water quality discharge and receiving water standards;
- Identification of potential risks;
- Contingency and emergency response plans;
- Access to MRMF areas potentially requiring future maintenance;
- Maintenance crew and equipment;
- Routine maintenance of water management systems;
- Routine inspections and maintenance of any access roads including erosion;

- Repairs and vegetation maintenance; and
- Inspections and non-routine maintenance after severe storm events, for example.

6.7.2. Monitoring and reporting

Long-term water quality, contaminant loading, and effects on wildlife and wildlife habitat will continue to be important monitoring issues for MRMFs during the post-closure stage. Environmental monitoring and reporting for the post-closure stage of any pile must be addressed in an overall environmental monitoring plan for the complete post-closure project for the mine site. Appendix G provides detailed information about the content expected in a comprehensive environmental monitoring program.

In recognition of the diminished potential for environmental effects, post-closure monitoring can be reduced from that performed during the closure period. However, post-closure monitoring for MRMFs must continue to provide information about water quality, contaminant loading and migration. It should also address wildlife and wildlife habitat to demonstrate that reclamation objectives are achieved.

Post-closure monitoring for MRMFs must continue for as long as the facilities present any physical or chemical risk.

7. References

The following references either have been cited directly in this document or are used by the Yukon government in its review of applications for quartz mining projects. Applicants are urged to refer to and use these documents when preparing material for submission to the Yukon government.

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Appendix A
Baseline Data Collection

February 2023

Yukon

Executive summary

The purpose of this document is to inform mining proponents early in the mine planning process of the specific baseline and site characterization information that the Yukon government expects proponents to provide during environmental assessment and permitting processes for quartz mining projects.

It is essential that proponents undertaking advanced mineral exploration read this document, meet with the Yukon government to obtain advice on monitoring plans and initiate baseline information collection as early in the exploration program as possible. The different components of any of the studies conducted should be planned and conducted by a qualified professional in the relevant field.

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1 Introduction

1.1 Purpose and scope of an environmental baseline study

Assessment and regulatory applications for quartz mining projects must be supported by sufficient environmental baseline studies to understand existing environmental conditions and to support environmental effects assessment, facility designs and operational assumptions. Such information must be based on measurements and observations from a recent period of at least three consecutive years for dynamic and variable environmental components. The data may include all available, relevant monitoring programs conducted by the proponent and past parties managing the site. The program must address the following types of data:

- atmospheric environment, including air quality and meteorological data;
- geological and geochemical data;
- surface hydrology data;
- hydrogeology;
- water quality;
- aquatic ecosystems and resources; and
- terrestrial ecosystems and resources including vegetation, surface soils, wildlife and wildlife habitat.

An environmental baseline program must collect, assess and interpret enough physical, chemical and biological information for the assessment and regulatory processes to:

- characterize aquatic, terrestrial and atmospheric resources that may be adversely affected;
- determine potential pathways of effects and impact mechanisms;
- identify terrain and environmental hazards;
- allow for the prediction of the significance of impacts and the effectiveness of proposed mitigation activities related to mine construction, operation, closure and post-closure;

- establish ecologically relevant and safe thresholds for those parameters that are indicators of ecosystem health and that will be used during the review process to determine significance of potential project impacts;
- facilitate the design of water quality and environmental effects monitoring programs that will allow for the evaluation of the actual impact on the receiving environment during and after the development of a project;
- establish methodologies that will be used through construction, operations and closure phases (both active closure and post-closure stages) of the project to evaluate project effects; and
- inform planned adaptive management responses.

The details necessary to meet the above requirements will depend on the complexity of the project and the accuracy and precision needed to predict project impacts. During the assessment and regulatory stages, a key objective of the baseline program is to support the proponent's prediction regarding the significance of potential impacts and to determine what strategies, if any, will mitigate those impacts. Once construction is initiated, and throughout the operations phase and closure phases, the objectives of the updated monitoring program are to:

- confirm that environmental conditions are consistent with predicted conditions;
- evaluate performance of site facilities, operations and systems, including compliance monitoring;
- support decision-making through an adaptive management plan; and
- evaluate attainment of objectives set for the project such as the water-quality objectives.

1.2 Expectations for the baseline study

This document provides the minimum expectations for environmental baseline studies and site characterization. Additional elements may be required on a site-specific basis.

Applications for quartz mining projects must contain and interpret environmental baseline data sufficiently specific and detailed so that the data provide an appropriate understanding of site-specific parameters, temporal and spatial ranges and variability. Environmental data presented in applications must cover a period of at least three consecutive years for variable and dynamic environmental components as described in Sections 1.2.2 and 1.2.3. Historical information may be used to augment a data set but does not replace the requirement for collection of recent and representative data. If historic information is used, limitations on its accuracy and precision must be identified.

Proponents are encouraged to continue the baseline monitoring throughout the application review periods, update data and refine modelling, and incorporate into licence applications. Using the most recent data will enable regulators to ensure licence conditions are effective, practical, site-representative and achievable in both current and future conditions.

It is recognized that different types and sources of baseline information have different temporal and spatial collection requirements to ensure the environmental conditions and the site are adequately characterized. For this reason, this document has split the requirements into three categories: static, variable and dynamic data; each of these is described below.

1.2.1 Static baseline data collection

Static data is considered to be the information collected for which natural conditions will not change on time scales that are relevant to the duration of all phases of the project. Geological information, physical and chemical properties of soils and vegetation communities[1] and contaminant concentrations in soil and vegetation are examples of environmental components where baseline conditions can be considered as static. Baseline data requirements for these types are described in Section 2.0 and Section 9.2 of this document.

For static data, the amount of data required to be collected is not temporal in scope but spatial. Study areas must cover the entire footprint of the site including access roads and any areas that may be affected by mining activities, for example within the air shed

[1] While vegetation is included in the “static” data category, the ability to measure and detect communities will be affected by the expected seasonal variability in vegetation.

or watershed as appropriate. Baseline data must also be collected in locations that will provide suitable reference data for comparison with future conditions in potentially affected areas.

1.2.3 Variable baseline data collection

Variable baseline data pertains to environmental components where conditions may vary seasonally or annually. Groundwater and surface water conditions, air quality and weather conditions are examples of variable baseline data. Variable baseline data collection requirements are described in sections 3.0, 4.0, 5.0 and 6.0.

For variable data, a sufficient temporal representation of the data must be presented for assessment and regulatory applications. Proponents are expected to present a minimum of three years of data for components that are considered variable, to provide a reasonable characterization of temporal variability both seasonally and annually. Specific monitoring frequencies may be adjusted, depending on the range of expected variability. For example, surface water baseline programs will require programs that collect data at least monthly during all seasons, augmented by more frequent sampling during periods of high expected variability such as freshet or convective summer storms. Groundwater conditions are often less variable and lower frequencies of monitoring may be warranted.

As with static data, study areas must cover the entire footprint of the site including access roads and any areas that may be affected by mining activities, for example within the air shed or watershed as appropriate. Baseline data must also be collected in locations that will provide suitable reference data for comparison with future conditions in potentially affected areas, and will remain accessible in all seasons, and through all phases of the project.

1.2.4 Dynamic baseline data collection

Dynamic data is considered to be the information about components where temporal and spatial distributions and conditions can vary greatly throughout the life of a project. Dynamic data are largely related to wildlife, wildlife habitat and aquatic resources.

The baseline data requirements for components are described in Section 7.0 and 9.3. Proponents should begin collection of dynamic baseline data early in the exploration stages and continue throughout project planning. A minimum of three years of observations and data collection are required, though this may not be sufficient to characterize distribution and conditions for some environmental components. Monitoring programs conducted by governments and other organizations are likely to be beneficial for comparative purposes, but are not a substitute for project-specific monitoring by the proponent.

Study areas for dynamic components should include the entire project area along with any access routes and flight paths where they may affect wildlife. For these components, study areas should include consideration of home ranges of potentially affected terrestrial and aquatic species. Definitions of study areas should consider species that currently use the area or have used it in the past. Baseline data should also be collected in locations and at times that will provide suitable reference data for comparison with future conditions in potentially affected areas.

1.3 Methods, instrumentation and QA/QC

Quality assurance and quality control (QA/QC) is important in every aspect of a sampling program, from program design through the fieldwork and finally to interpretations of results. Consistent and rigorous QA/QC practices will enable collection of meaningful and scientifically credible data. For certain data types, assessors or regulators require that data sets be accompanied by a QA/QC report to demonstrate how data was collected, sampled and stored. Results and conclusions resulting from data and practices that do not meet accepted QA/QC guidelines may be rejected by assessment and regulatory agencies.

Data collection must be based upon industry standard methodology such as Canadian Standards Association (CSA) or American Society for Testing and Materials (ASTM) as appropriate. Before environmental baseline studies commence, proponents are encouraged to meet with the Yukon government, YESAB and the Yukon Water Board to ensure the methodologies and instrumentation proposed meet the expected standards.

1.3.1 Conceptual site model

The design of baseline monitoring and site characterization programs should begin with the development of a conceptual site model. A conceptual site model identifies all environmental components and existing and proposed human activities, and it then defines the understanding of relationships between these components and activities. This provides a framework for identifying interactions between the environment and the proposed project and describing pathways for potential effects. The framework can be used to define the questions that baseline monitoring and site characterization programs need to address and identify what information is currently known or not known about the environment and the site.

A conceptual site model is composed of a set of hypotheses that describes the predicted relationships between environmental components and potential stressors, and the potential pathways, exposures and responses. This requires information on the natural processes that influence environmental conditions, the sources and releases of stressors that may affect environmental components, the pathways by which environmental components may be exposed to stressors and the potential effects these stressors may have on environmental components. The relationships, pathways and effects are usually illustrated by a series of diagrams.

2 Geology and geochemistry

2.1 Purpose and objectives

Assessment and regulatory applications must be supported by a comprehensive understanding of site-wide and component-specific geology and geochemistry. This work includes characterizing the physical characteristics and metal leaching and acid rock drainage (ML/ARD) potential of all materials that may be used or disturbed throughout the life of the project. The primary purposes of a detailed geological and geochemical monitoring are to:

- characterize the physical environment of the project area in its current state;
- determine the composition and characteristics of the materials to be disturbed;

- identify potential impacts that the disturbance of these materials may have on the receiving environment and the degree and magnitude to which these impacts could occur; and
- support the design of the project in order to eliminate, reduce or mitigate potential impacts on the receiving environment.

The geologic component of a mine development is the fundamental basis for the project's existence and therefore will comprise a significant portion of the initial information collected. The deposit type, location, physical environment, permafrost conditions, mineralogy, geochemistry, structure and other features will determine the economics, development strategy, potential short- and long-term environmental issues and ultimately the legacy of a given project.

Permafrost conditions, especially in overburden materials, is an important consideration in all areas of physical land disturbance. Disturbance can lead to degradation of permafrost, which can affect long-term physical stability of the site and mine facilities.

The geology of the deposit and how it reacts to ambient conditions once exposed, as well as mining and processing influences, will impact the drainage chemistry and ultimately the receiving environment. The detailed characterization of the deposit and other disturbed areas enables early predictions of potential changes to the water quality emanating from the deposit area and associated infrastructure and forms the basis for the mine design, monitoring requirements, treatment options and other operational and post-closure considerations.

A major concern with all mineral development projects is the potential for short- and long-term ML/ARD development, its potential impact on the receiving environment and the operator's ability to prevent its occurrence or mitigate its impacts.

2.2 Data collection

Proponents are required to collect baseline information on all materials and locations that may be disturbed throughout the duration of the project. Collection strategies should include:

- regional and local surface geology mapping;

- drilling or surficial geophysical studies to define geology and related structural features;
- stream sediment and surface/seep water sampling surveys to characterize regional and local geochemistry and water chemistry;
- robust evaluation of the mineralogy of the various rock unit present in the project area to assess the potential for metal leaching;
- overburden mapping and sampling for characterization and geochemical signatures;
- identification of surface features such as gossans, vegetation dead zones, etc.;
- characterization of permafrost including presence, temperature, material properties and water/ice content;
- mapping and sampling of trenches;
- logging and sampling of drill cores; and
- test pits.

During this work, detailed geologic and initial mill process characteristics must be identified, including the lithology, mineralogy, structure, alteration, distribution, metal recovery, milling requirements and many other features. This deposit baseline information is critical in determining what the potential effects of the mining project may be on the receiving environment.

Applications will require the following general information to assist in a balanced evaluation. The proponent must have the information required to:

- characterize and quantify ML/ARD potential of all materials to be disturbed during site development;
- identify, develop, characterize and segregate materials acceptable for construction purposes;
- characterize and quantify locations and materials subject to permafrost;
- evaluate the lag time to ARD onset (if applicable) for materials to be exposed and the significance of any ML/ARD generated;
- design and construct a sound mining project that minimizes the amount of potentially acid generating material exposed; implement and maintain mitigation strategies during the life of the mine and post-closure;

- contain and collect ML/ARD originating from any site-related sources during operation and post-closure;
- evaluate the quality and characteristics of surface, seepage and ground water potentially influenced by the development;
- bring confidence and certainty in expected performances of mine facilities and infrastructures including for post-closure ARD collection, treatment, prevention, mitigation, monitoring and maintenance; and
- design a project for which infrastructure and financial responsibility can be maintained.

More specifically the application should include:

- a description of the regional geology in relationship to the project at a map scale that is no less detailed than 1:250,000;
- a description and map of the property geology, including drill hole locations and type;
- a description of the major rock types present, indicating petrology, mineralogy, and structure;
- The identification soil structure and stability as it relates to compaction and erosion;
- for surficial materials intended for use as construction or foundation materials for structures, a description of grain size, permeability, ice content, moisture content and density, and any other relevant physical, geochemical and geotechnical properties;
- details on terrain mapping, soil classification and erosion potential. Descriptions should include consideration of attributes that influence or facilitate runoff, such as infiltration rates, percolation, slope, aspect, vegetation and presence of permafrost;
- for permafrost areas within the project area, a characterization of the spatial extent, temperature, moisture content, thickness, thaw stability (and criteria used to assess), and stability of material;
- for projects anticipated to alter the surficial geology, pre-disturbance surficial geology information for the purpose of eventual decommissioning/ reclamation of the project; and

- presentation and description of all geochemical results of all lithologies in the project area. Data and results from acid-base accounting, kinetic testing, slaking, freeze thaw, and metal leaching tests should be presented and discussed. The acid-neutralizing capability of the different rock types should also be provided.

This geology and geochemistry baseline data collection will be used to fully characterize all materials being disturbed as a result of the project for metal leaching and acid rock drainage potential and the appropriate segregation or storage requirements.

Proponents are encouraged to follow the methodologies presented in *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1* when finalizing field programs for data collection. Cold weather specific considerations must be taken into account when developing geochemistry programs and determining the acid generation, neutralization or metal leaching potential of disturbed material.

3 Atmospheric environment

The baseline information collected for the atmospheric environment, as outlined in the sections 3.1 and 3.2 below, will play particular importance in the characterization of the observed climate and consideration of climate change effects at a project. It is important that collection of data is consistent across disciplines, or provide a rationale of why collection methods differ, to ensure an accurate characterization of the observed climate can occur.

Section 8 of this document provides further instruction for the collection and use of data as it relates to climate change.

3.1 Meteorology and climate monitoring

3.1.1 Purpose and objectives

The purpose of a meteorological study is to characterize the atmospheric environment in its current state and to develop an understanding of:

- the range and variability of weather conditions;
- potential impacts that weather and climate can have on a project, especially extreme events;
- potential impacts that a project can have on air quality and the hydrological environment; and
- inputs to hydrological and water balance models used to design and manage a project (e.g., infiltration, evaporation, runoff and snow sublimation).

Wind speed and direction data are required to predict the distribution of trace metals in soils from fugitive dust derived from tailings and waste rock piles. They are also needed to select sites for long-term camp and mineral processing facilities in order to accommodate predominant wind patterns and to predict and mitigate the effects of fugitive dust and associated trace metals. Air temperature, net radiation, wind, turbulence and precipitation data are also required for atmospheric dispersion modelling, and there may be a need for additional measurements at various levels above ground. Such modelling is required for environmental assessment reviews to determine a project's potential effects on ambient air quality.

Regional and site-specific precipitation and snowpack data are necessary for runoff prediction and calibration of hydrological models. Solar radiation and evapotranspiration data are also required to estimate parameters for the design of water management infrastructure and to plan for closure.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

Because it is important to understand extreme events, particularly in the context of a changing climate, meteorology and climate data collected as part of baseline programs will not be sufficient to characterize conditions to support project planning and design. Instead, the collection of site-specific meteorology and climate data is intended to support correlation of site conditions with long-term records from regional programs.

3.1.2 Monitoring site selection

To ensure that meteorological stations collect representative data, stations and sensors must conform to standards set by both the federal and territorial governments. Proponents should identify potential sensitive receptors in the area prior to establishing sampling sites.

In mountainous terrain, meteorological conditions can vary greatly from valley bottom to alpine elevations and from one valley system to another. For this reason, depending on the size of a project, a proponent may need to install more than one meteorological station. Multiple stations should be considered for large projects with heterogeneous topography and land coverage to address the variability in elevation and microclimates. A proponent is expected to demonstrate an understanding of weather and climate over a project's entire footprint, including upstream and downstream environments. This understanding should be proportional to the potential for weather and climate to impact a project; professional judgement or external expertise must be used to determine the necessary extent of the meteorological monitoring network.

3.1.3 Data collection

The parameters deemed necessary will vary depending on the scope of the proposed project, the magnitude and type of emissions, and the sensitivity of the airshed, watershed and ecosystems. Below is a list of parameters that the proposed baseline study for meteorology, air quality and climate should consider:

- Hourly precipitation for rain and daily precipitation for snow
- Daily snow depth and monthly snow water equivalent
- Hourly air temperature for all seasons
- Hourly relative humidity
- Hourly wind speed and direction
- Hourly incoming, outgoing and net radiation
- Sub-monthly soil temperature and moisture

3.1.4 Frequency and period of record

In order to create a valid baseline dataset and continuously improve data representativeness, a proponent should begin to collect high-quality data at the inception of the project and continue collection through the entire project life. Proponents should conduct a review of existing atmospheric information of the site and surrounding region as a part of project planning; historical information will be useful in the identification of trends and site characterization. Given the changing climate context, it is important to emphasize the most recently collected data on site and to keep track of historical regional conditions and future projections. Regional data should be used to complete the baseline dataset, but it can never replace site-specific data.

The minimum sampling requirements for a project is one local station with a period of record of 36 continuous months. Project specific requirements for the sampling frequency and period of record will be determined according to the scope of the proposed project and whether or not there is a requirement to input meteorological parameters into an atmospheric dispersion model.

Proponents must consult with the Yukon government to reach agreement on whether dispersion modelling is required, and if so, which model is appropriate. As different atmospheric dispersion models have different data input requirements, model selection is a critical driver of meteorological monitoring requirements. Proponents should refer to the “British Columbia air Quality dispersion modelling guideline” when developing a dispersion model.

3.2 Air quality monitoring

3.2.1 Purpose and objectives

In the Yukon, proponents must ensure that air quality at a site is maintained at a level that does not harm the natural environment or public health or safety. The purpose of monitoring baseline air quality is to characterize the current state of the substances in the atmosphere and to develop an understanding of:

- potential incremental influences that a project can have on air quality in the surrounding area;
- potential influences that a project can have on the air quality of neighbouring communities; and
- potential cumulative influences that a project and existing emission sources in the area can have on air quality.

In pristine environments and in areas close to communities, it is important that the proponent demonstrate a clear understanding of baseline air quality, so that project effects can be adequately modeled and monitored and to ensure that air emissions from the project do not exceed Yukon ambient air quality objectives.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

Applications for assessment and regulatory purposes may require atmospheric dispersion modelling. Determining background air quality concentrations is an essential component of this task.

3.2.2 Monitoring site selection

To ensure that air quality stations collect representative data, stations and sensors must conform to standards set by both the federal and territorial governments. Proponents should identify potential sensitive receptors in the area prior to establishing sampling sites.

In mountainous terrain, meteorological conditions can vary greatly from valley bottom to alpine elevations and also from one valley system to another. For this reason,

depending on the size of a project, a proponent may need to install more than one air quality station.

3.2.3 Data collection

The parameters deemed necessary will vary depending on the scope of the proposed project, the magnitude and type of emissions, the sensitivity of the airshed and ecosystems and whether or not there is a requirement to input meteorological parameters into models. Below is a list of parameters that the proposed baseline study for air quality should include, but is not limited to:

- hourly mean temperature;
- hourly relative humidity;
- wind speed and direction;
- net radiation;
- total suspended particulates, PM_{10} and $PM_{2.5}$; and
- oxides of nitrogen and sulphur.

Winds are typically measured at 10 m above ground, but measurements at greater heights may be required depending on the emission source. For example, if the emissions are from a 60 m stack, consideration should be given to measuring wind at elevations that are more representative of the conditions experienced at the point of emission.

To ensure completeness of the data set, maximum, minimum and mean values must be presented for all parameters.

3.2.4 Frequency and period of record

In order to create a valid baseline dataset and continuously improve data quality, a proponent should begin to collect high-quality data at the inception of the project and continue collection through the entire project life. Extensive monitoring may be required, especially for major projects located in sensitive airsheds. Monitoring should be taken for 24-hour periods during one week of each month.

The minimum sampling requirement for air quality is one station with a period of record of 36 months. Project-specific requirements for the sampling frequency and period of record will be determined according to the scope of the proposed project, the magnitude and type of emissions, the sensitivity of the airshed and ecosystems, and whether or not there is a requirement to input air quality parameters into an atmospheric dispersion model. Proponents are encouraged to consult with the Yukon government to reach agreement on what type and frequency of monitoring is required for a site.

4 Hydrology

4.1 Purpose and objectives

The purpose of the hydrologic study for a proposed quartz mining project is to characterize existing surface water resources and to estimate the impact that the project is expected to have on these systems. Similarly, a thorough understanding of the water management needs associated with the mine proposal is required to correctly design water systems such as milling or leaching processes, tailings impoundments or heap leaching facilities, treatment plants, sedimentation ponds, culverts and diversion ditches and to clarify post-closure water management scenarios. The main objectives of the baseline hydrology study are to:

- provide calibration data for the development of integrated mine site and receiving environment water balance models;
- evaluate the range and variability of seasonal hydrological patterns (including intermittent/ephemeral streamflow); and
- provide annual and event-specific data for flow frequency analyses (i.e., low flows, peak flows, etc.).

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. The assessment is expected to be performed to the current standard of professional practice by an appropriate qualified professional.

4.2 Review of existing hydrology information

Proponents should conduct a review of existing information on the surficial hydrology of a site and the surrounding region as a part of project planning. The review should, at a minimum, include information from the following sources:

- reports and literature about the site hydrology and nearby watersheds (from other mining projects);
- Water Survey of Canada and Yukon water resources branch stream flow records and a regional analysis of baseline hydrological parameters, using these data (including data from the Yukon Water Data Catalogue);

- a regional analysis of liquid precipitation, incorporating intensity-duration-frequency curves for nearby Environment Canada stations, and taking climate change projections into account;
- regional (spatial and elevation) analysis of solid precipitation and snow water equivalent (including data from the Yukon Snow Survey Network); and
- existing water users, community watersheds, and traditional users.

The above information should be used to provide an outline of the general characteristics for the bio-geoclimatic zone, catchment areas, watercourses and waterbodies that may be affected by the project. These characteristics should include without limitation:

- maps including basin delineations, existing or proposed climate stations and an outline of the project site;
- basin topography and area;
- source areas including groundwater and glaciers;
- bio-geoclimatic zones;
- critical wetland/riparian areas;
- diversions (including roads, ditches and other infrastructure that would act as a diversion);
- stream crossings;
- dams and dikes;
- streamflow consistency (e.g., perennial, intermittent and ephemeral) and;
- monthly distributions of temperature, precipitation and streamflow from regional stations.

4.3 Monitoring site selection

Many phases of the environmental assessment and subsequent permitting process depend on reliable hydrometric data. The proponent must consider that hydrometric stations will need to operate for several years; therefore, correct siting and a durable installation will be key to generating a consistent hydrometric dataset that is adequate for assessment and regulatory processes. In addition, reliable and accurate hydrometric data will be required during all other phases of the mine life, including operations and closure.

Proponents should refer to the Manual of British Columbia Hydrometric Standards when establishing hydrometric monitoring sites and developing the monitoring program.

Multiple stations within the study area will be necessary to adequately characterize the dynamics of the surface water systems and to ensure data gaps can be filled in the event of equipment malfunction. The final decision on the selection of gauging sites requires information on physiographic features and conceptual mine plans.

When establishing a hydrometric network, the proponent should first consider the data needs of the project as a whole in terms of accuracy, seasonal coverage and spatial extent. There are many useful and objective statistical methods for network design; the definitive network configuration will rely on the professional judgement of a hydrologist. The network design should be based on experience and on peer-reviewed literature sources and should, at a minimum, address the following considerations:

- The potential perimeter of the project footprint and the required accuracy of the data to be collected;
- For projects with a high degree of topographic variability, installing meteorological and hydrometric stations at varying elevations in order to quantify the effect of elevation on precipitation/runoff ratios;
- Glacial outflow should be measured, as this can substantially increase summer flows;
- The availability of useful historic regional data is complementary to the design of the project hydrometric network;
- Network design must reflect the proposed mine plan, probable discharge locations and diversion locations, or anywhere that flows might be affected;
- Sites must be chosen that will provide an accurate representation of all inflows and outflows to the affected areas;
- Stations must be situated in an area where they are unlikely to be moved as a result of construction/operation/closure activities, so that baseline data can be

compared with the monitoring data collected as part of the ongoing operation/closure of the mine;
- Discharge rates in low flow, winter conditions should be well characterized as low-flow conditions are critical to define future effluent quality standards;
- All monitoring sites for surface water must be geo-referenced and photographed from different angles to show the physical characteristics of the gauging site;
- For all hydrometric monitoring sites, it is mandatory that staff gauges are surveyed periodically and controlled for shifts in elevation against fixed reference points (or benchmarks). Reference points or benchmarks must be accessible during all water levels, and should be evaluated for stability;
- Installation of an automated stage recorder that collects water depth measurements at regular and frequent intervals (hourly or sub-hourly for smaller basins with rapid response times) is necessary for most sites in order to capture the dynamics of specific hydrological events; and
- Similarly, choosing equipment that can be take measurements year-round is recommended.

4.4 Data collection

Hydrometric stations should collect and record continuous water level data that can be used to calibrate surface-water models. Such data improve temporal resolution and reduce the risk of missing critical events.

Frequent discharge measurements are required to develop site-specific rating curves that allow continuous water level data to be converted to discharge estimates. Accurate discharge measurements are central to providing the necessary data for all aspects of the hydrology baseline study and subsequent mine water-management programs. Attempts must be made to make discharge measurements during high water events to help define the full range of seasonal variability.

Several methods are available for calculating discharge, and the suitability of a given method will depend on the streamflow, channel characteristics at the measurement site and professional judgement.

Data must also be collected for wetlands, ponds and lakes including an estimate of water body volume, bathymetry, inputs and outputs and estimated retention times. The occurrence and timing of the waterbody stratification and seasonal mixing patterns near the proposed points of project discharge must be included in assessment and regulatory applications.

4.5 Winter and ice-affected hydrology

Surface discharge measurements should be collected during both open-water and ice conditions. Winter discharges are important for a number of assessment and permitting purposes such as base flow/low flow estimates and assessing impacts to the aquatic ecosystem. Flow measurements under ice or during winter conditions can be difficult to perform and instrumentation may be adversely affected by cold weather conditions. Freeze-up and break-up dates for each watercourse/body must be identified along with if/when the watercourse/body freezes to ground.

Specialized equipment and techniques will be needed to safely and accurately collect winter data. Salt-dilution methods have been shown to successfully measure winter flows in many small Yukon streams. Additionally, the use of wildlife cameras to monitor ice-conditions is an increasingly used technique to identify freeze-up and break-up as well as potential dynamic mid-winter ice processes.

A reliable stage-discharge relationship does not exist under ice-affected conditions (with rare exceptions), in which case frequent discharge measurements, index (indirect) methods or other techniques may be required to establish a suitable data record.

Regardless, winter hydrometric data of known and acceptable quality is achievable and necessary to adequately assess the impact of a proposed project, especially if the critical low flows occur during the winter (special attention should be dedicated to the freeze-up period and to the end of winter period, prior to snowmelt runoff).

4.6 Frequency and period of record

Continuous water level data and frequent discharge measurements must be collected in order to evaluate the accuracy of rating curves and to characterize the channel mobility, if any. For small streams, a water level record interval of 15 minutes is suitable whereas for large streams, hourly records are often acceptable. This minimum requirement also allows more robust comparison with regional data, allows relationships to be developed and validated with on-site and regional precipitation data and allows the proponent to address gaps or errors that occur during the initial years of data collection.

The site-specific hydrometric data must be of sufficient accuracy and record period to enable meaningful and statistically significant relationships to be developed with regional data sets and to constrain the probable range of hydroclimatic conditions at the site of interest. The length of hydrologic record required for a baseline hydrology study will vary depending on the quality of existing on-site data and nearby stations or regionalized data, and it may be longer than 36 months. The hydrologist should provide a rationale for the acceptable accuracy of all hydrologic parameter estimates in order to allow an objective determination of the necessary length for the hydrologic record.

It is useful in the project design phase to have a general sense of the accuracy of the design input data in order to avoid the under- or over-design of project infrastructure.

5 Hydrogeology

5.1 Purpose and objectives

The purpose of a hydrogeology study for a proposed resource development project is to define and assess the potential environmental effects from that development on the groundwater and interrelated surface water resources and to develop prevention, mitigation and monitoring measures to ensure that the quantity and quality of the groundwater resource are maintained for present and future uses. The main objectives of the baseline hydrogeologic study are to:

- provide baseline information on the extent, physical and chemical characteristics, uses and potential of the groundwater resource in and around the proposed development for subsequent water quantity and water-quality impact prediction and monitoring;

- outline mitigation measures to ensure that the groundwater resource is maintained for present and future uses;
- characterize the pre-development groundwater flow regime to develop a conceptual groundwater model and to calibrate a numerical flow model;
- evaluate seasonal changes in groundwater flow patterns, groundwater levels and groundwater quality, where applicable; and
- delineate/map groundwater flow paths and possible changes to flow and quality resulting from proposed developments.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a hydrogeology monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

5.2 Review of existing hydrogeology information

A compilation of existing information on the groundwater resources of the study area should be conducted prior to collection of field data. Local groundwater resource information includes the following and other related sources:

- published geology and hydrogeology reports and aerial photographs;
- soils and geologic maps and aquifer classification mapping;
- Yukon Water Well Database and Yukon Observation Well Network;
- exploration test holes, trenches and test pits;
- geophysical information (e.g., aerial survey, borehole logs, etc.);
- aquifer response test results (e.g., pumping tests, packer tests, tracer tests, etc.);
- geotechnical information (e.g., rock quality, packer tests, soil classification, etc.);
- on-site photographs;
- seepage information and seepage quality data;
- data demonstrating ground water and surface water interactions (e.g. piezometers, mini-piezometers and seepage meters);
- information from structural geology studies (including regional structures and stratigraphy and detailed site-specific structural geology assessments);

- Digital Elevation Model (DEM) for both surface water and groundwater modelling (note: the DEM may need to be corrected by "ground-truthing" to surveyed points); and
- historic climatic data available through environment and climate change Canada's database.[2]

5.3 Monitoring site selection

Monitoring sites must be established to collect data on groundwater levels and groundwater quality. Monitoring wells which measure both groundwater level and quality must also consider the requirements presented in Section 6.0 of this report. Monitoring sites must be geo-referenced and photographed from different angles to ensure they can be recognized and mapped. It is recommended that sites be surveyed for geodetic elevation, specifically with reference to ground (or top of casing) elevation at the monitoring well location.

The design of a groundwater monitoring system requires careful analysis and must be completed by a qualified environmental professional with expertise in hydrogeology. The monitoring objectives must be kept foremost in mind when siting, designing and constructing the well. When the general location for monitoring baseline water levels is chosen, the specific site should be, as much as possible, minimally affected by nearby pumping and future infrastructure.

The site investigation plan must consider the groundwater characterization advice for contaminated site investigations in the contaminated sites regulation protocol No. 10: Determining background groundwater quality. The type and amount of baseline hydrogeologic data that must be obtained will depend on the complexity of the geologic setting, the size of the assessment area, the types of impacts that can be anticipated from the proposed operations and the degree of confidence needed in the site characterization to make sound project assessments. Proponents must ensure that groundwater data have sufficient spatial and vertical coverage to characterize the three-dimensional groundwater flow regime at the site and up-gradient and down-

[2] Historical Data - Climate - Environment and Climate Change Canada (weather.gc.ca)

gradient of the site, and to understand the interactions between groundwater and surface water. Additionally, the monitoring program must consider the life cycle of the project with monitoring sites established after considering expected operational and closure activities.

Monitoring sites must not be selected simply for the purpose of providing broad spatial coverage. For each monitoring site, the proponent must be able to articulate the issue or question that can be resolved by obtaining data at that location. Some examples for selecting groundwater monitoring sites include:

- understanding local and regional hydrogeological processes and characteristics, e.g., groundwater discharge and recharge areas;
- quantifying the degree of groundwater interactions with surface water;
- biological importance of groundwater in streams, e.g., baseflow component of streamflow;
- designing future operations such as pit dewatering; and
- understanding the impact of past, current or future contaminant plumes.

In a similar fashion, the selection of monitoring sites and data to be collected at each site must be undertaken with specific forethought given to the data required for impact prediction. When planning baseline data collection, it is helpful to consider how the attributes of the data may also contribute to a reduction in prediction uncertainties associated with subsequent impact predictions.

At a minimum, a sufficient number of groundwater monitoring locations must be established within a given permeable hydrostratigraphic unit (aquifer) to adequately determine groundwater flow directions and hydraulic gradients. A representative number of monitoring wells must be up-gradient from the proposed mine for background control and to establish groundwater level trends before the project begins and for the duration of the project.

Monitoring must be representative of different hydrostratigraphic units (e.g., shallow unconsolidated aquifers must be monitored separately from deeper bedrock units). Spacing of monitoring wells and screen intervals will depend on the degree of uniformity of the hydrogeological setting and appropriate representative scale of measurement.

All permeable units potentially affected by mine works must be monitored to provide an understanding of vertical hydraulic gradients. Even in the case where surficial and bedrock units have generally low hydraulic conductivity, monitoring wells are required to characterize the groundwater system. The preceding generalizations need to take into account both site-specific hydrostratigraphy and the mine plan.

Monitoring well construction must conform to the minimum construction standards in the Yukon contaminated sites regulation protocol No. 7: groundwater monitoring well installation, sampling and decommissioning.

5.4 Data collection

Hydrogeologic measurements supplement existing information for the assessment, prevention, mitigation and monitoring of potential environmental effects from the project and provide site-specific data. In addition, hydrogeologic measurements are needed to delineate groundwater flowpaths for determining impact pathways.

Field investigations are intended to:

- provide baseline information on geology, hydrogeologic properties, boundary conditions, surface water hydrology, groundwater flow (directions, velocities, and mass flux rates), surface and groundwater quality, groundwater–surface water interactions and site water balance;
- support the development of groundwater flow models;
- allow for preliminary design and assessment of mitigation measures;
- allow for assessment of residual impacts following implementation of mitigation measures;
- allow development of an ongoing monitoring program; and
- identify issues that may influence post-closure behaviour of the mine site.

If possible, field investigations must include methods that will characterize hydrogeologic variables at appropriate spatial and temporal scales (e.g., pumping tests to establish hydraulic properties for dewatering, etc.) and boundary conditions.

The hydrogeologic field investigation and data collection must include the following aspects of groundwater investigation:

- inventory of neighbouring well users and regional groundwater use (including First Nations users) and surface water use;
- measurement of water levels in surface waters, including any mine pits, as these data may be essential to interpretation of groundwater levels and flow;
- characterization of site geology and hydrogeologic properties using specific techniques, which may include:
  - conducting pumping tests at all appropriate scales (e.g., small vs. large, long-term vs. short-term) and interpreting the results;
  - aquifer response tests (e.g., packer tests, slug tests);
  - bench-scale or field-scale material testing;
  - borehole geophysics/borehole flow meters; and
  - tracer tests and surface geophysics;
- baseline monitoring of water levels and water quality from:
  - on-site wells and exploration boreholes
  - natural discharges, and
  - local or site-scale streams.

Field data collection should allow the proponent to adequately characterize the groundwater flow system and identify aquifers and boundary conditions, hydraulic properties, water budget and groundwater–surface water interactions with adequate certainty. At mine sites where there is likely to be a groundwater–surface water interaction, proponents are required to assess the relative contribution of groundwater to surface water. This is often done using water chemistry or installation of piezometers.

Both regional and local scale numerical models may be required to understand the groundwater and its relationship to surface water and flow regimes at the site. Regional models should address groundwater characteristics and influences over the entire mine footprint and affected aquifers, while local models should address specific mine components. In this context, the term “modelling” refers to the use of computer-based numerical methods to obtain approximate solutions to the coupled equations of groundwater flow and solute transport.

Groundwater flow simulations require an understanding of geology and the hydraulics of groundwater flow as well as a command of numerical simulation methods. When solute movement is to be simulated, the complexity of the problem increases. Data requirements for a numerical model include site-specific information on:

- unconfined and confined aquifers: groundwater flow and storage changes, fine-grained confining units and interbeds;
- faults and other barriers: resistance to horizontal groundwater flow, potential for faults to be conduits for groundwater flow;
- confining units: groundwater flow and storage changes;
- rivers: exchange of water with aquifers;
- drains and springs: discharge of water from aquifers;
- ephemeral streams: exchange of water with aquifers;
- reservoirs: exchange of water with aquifers;
- wells: withdrawal or recharge at specified rates;
- recharge from precipitation and irrigation water use;
- permafrost, and
- evapotranspiration.

5.5 Frequency and period of record

The frequency of sampling must be commensurate with the processes being observed. For the groundwater quality baseline, the recommended minimum period of record is three years of quarterly data. This is the minimum period required to assess seasonal variations during the initial project evaluation phase. Attempts must be made to make measurements or collect samples at times of maximum/minimum hydrogeological conditions to define the full range of seasonal variability.

For groundwater quantity, it is preferred to record continuous water-level data using water-level sensors (i.e., daily measurements are preferred for key monitoring wells). For the groundwater quantity baseline, the recommended minimum period of record is three years of continuous water-level measurements to understand the groundwater level variability at the mine site.

The monitoring program will continue, with adjustments as necessary, throughout the life of the project and post-closure.

6 Surface and groundwater quality

6.1 Purpose and objectives

Water quality describes the physical, chemical, biological and aesthetic characteristics of water, which strongly influence its suitability for aquatic life, wildlife, livestock, irrigation, human consumption and industrial use. Contaminants may be dissolved or suspended in the water column, through which they can be transported off site, taken up by organisms, or transferred to other matrices, where they may cause significant impacts. Thus, water-quality information provides a crucial component of mine baseline, project impact, operational and post-closure assessments.

The main objectives of water-quality monitoring related to mining are to:

- determine the water-quality conditions in the project area, including total suspended solids, nutrients, major ions, metals (total and dissolved for surface water, dissolved for groundwater), turbidity, pH, conductivity, dissolved oxygen and temperature or other parameters that might be required for specific sites;
- assess the ambient surface and groundwater conditions before effects from the proposed activities occur;
- identify any seasonal variability and range of water-quality variables focusing on water characteristics that may be modified by the project during any phase;
- identify whether baseline concentrations naturally exceed water-quality guidelines and to choose a water management approach to identify water-quality objectives;
- Identify contaminants of potential concerns for which water-quality objectives need to be established;
- determine the need for and level of monitoring and management during construction, operations, closure and post-closure;

- support water-quality modelling and prediction;
- allow the comparison of baseline data with operational and post-closure water-quality data to identify whether water quality is affected by mine-related activities; and
- verify that established water-quality guidelines or objectives are being met and water quality is being protected.

Water quality assessments must be conducted by a qualified professional who has experience relevant to the specific subject.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a water-quality monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

6.1.1 Review of existing water-quality information

A compilation of existing information on the water quality in the study area should be conducted prior to collection of field data. Water quality resource information includes the following and other related sources:

- Water quality data from Environment Canada's water-quality monitoring program and through the water resources branch of the Yukon's Department of Environment;
- Published geology and hydrogeology reports and aerial photographs;
- Soils and geologic maps and aquifer classification mapping;
- Yukon water well database and Yukon observation well network;
- Exploration test holes, trenches and test pits;
- Geophysical information (e.g., aerial survey, borehole logs, etc.);
- On-site photographs;
- Surface water and groundwater interaction data; and
- Historic climatic data available through environment and climate change Canada's database.[3]

[3] Historical Data - Climate - Environment and Climate Change Canada (weather.gc.ca)

6.2 Monitoring site selection

Proponents are encouraged to discuss sampling locations with the Yukon government before beginning a water-quality monitoring program. All sites for both groundwater and surface water-quality monitoring must be geo-referenced, mapped and photographed from different angles. It is prudent to include as many sites as possible early in the baseline study, with the intent of eliminating some sites once potential and actual impacts from mine facilities and the water-quality variability and trends are better understood. All catchment areas, water courses and water bodies that may be affected by project activities must be included in the water-quality baseline program.

6.2.1 Surface water

Sampling sites must be established in all areas potentially affected by the proposed construction, operation and closure phase of the mine and in areas that will not be affected by mining operations. This includes upstream and downstream of all proposed discharges, seepage points, and non-point contaminant sources. When selecting the downstream station of an effluent discharge, the proponent should refer to Section 6.3 mixing zones of the *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects* to determine an appropriate distance from the proposed effluent discharge location. Far field sites need to be established where downstream or cumulative effects can be anticipated. All sampling sites selection needs to take into consideration year-round accessibility during baseline and mining to prevent data gaps and site relocations.

Reference sites must be established upstream of all mining areas in each potentially affected watershed. Where proposed mine development in the headwaters prevents the establishment of upstream reference sites, other suitable reference sites, such as adjacent watersheds with similar catchment areas and geologic settings, must be considered for data collection during the baseline period.

Water quality and surface flows should be monitored at the same locations so that loading calculations and predictions of downstream receiving water concentrations can be made and compared with water-quality objectives. Accurate loading calculations and predications are particularly important at proposed compliance sites, where water quality will have to meet licence conditions or water-quality objectives during construction, operation and closure, and to accurately characterize each season and each watershed and sub-watershed.

6.2.2 Groundwater

The main goal of groundwater quality monitoring site selection is to establish baseline conditions and allow for trend assessment of groundwater conditions. Monitoring wells must be installed both up-gradient and down-gradient from any areas with potential seepages from mine facilities (such as the foot of tailings impoundments). In addition, at locations where mining impacts are possible at more than one depth, nested or multi-level monitoring wells must be installed to different depths. Special groundwater well design will be needed for wells developed in frozen ground.

For baseline conditions, water quality in the mineralized zones to be mined must be sampled and assessed separately from ambient, down-gradient or down-flow groundwater quality. Monitoring locations and monitoring priorities should be expected to be modified during the life of the mine.

An appropriate number of monitoring wells to provide adequate representation of ambient groundwater conditions in the project area should be located immediately up-gradient from all potential mine influences. Wells that are destroyed by site activities should be replaced if a continuing data record is needed. Where wells are no longer required, they should be properly abandoned.

6.3 Data collection

When developing a baseline, a full suite of analyses is required to provide a complete picture of the natural constituents in the water. During operation and post-closure, analytical work may be reduced depending on a supporting rationale and findings that certain constituents are below detection limits or not affected by mine operations. The detection limit for each water-quality parameter of interest must be less than the respective water-quality guideline, ideally by one order of magnitude. These detection limits may not be achievable by all laboratories or for all samples.

When developing a sampling program proponents are required to follow the methodologies and protocols identified in *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects*[4] for the development of water-quality objectives and determination of effluent quality standards. In addition to Yukon's specific guidance document, proponents are encouraged to consult the Canadian Council of Ministers of the Environment *Protocols Manual for Water Quality Sampling in Canada.*

6.3.1 Surface water

Baseline water-quality sampling must characterize spatial and temporal variations in water-quality parameters over the project area. Measurements of surface water-quality parameters relevant to the project must be collected on a minimum monthly basis for a period of at least three years with one or more intensive sampling programs each of the three years, with at least five samples collected in 30 days during periods of high expected short-term water-quality variability. Sensitivity/uncertainty analyses and multi-year sampling must be included to estimate inter-annual variability.

The water-quality sampling program must characterize spatial and temporal (seasonal) variation in water quality through the year. Sampling must capture annual peak and low flows in flowing waters and stratified and non-stratified conditions in ponds/lakes. Water-quality parameters to be measured must include at least a full metals suite (total and dissolved), total suspended solids, turbidity, pH, conductivity, dissolved oxygen, nutrients and temperature and any other parameters relevant to the project.

6.3.2 Groundwater

Baseline groundwater quality sampling must characterize spatial and temporal (seasonal) variation in groundwater quality parameters over the project area. Measurements of water-quality parameters relevant to the project must be collected on a minimum quarterly basis for a period of at least three years to estimate seasonal and inter-annual variability. Water-quality parameters to be measured must be comprehensive and should be determined in discussion with the Yukon government.

Sampling stations must be situated to provide adequate spatial coverage relative to the project including both reference/control locations and potentially affected stations. Where possible, sampling stations must be established at sites suitable as future monitoring and compliance points.

7 Aquatic ecosystem

7.1 Purpose and scope

Most mining projects lead to changes in water flow and quality in local watercourses. These changes can adversely affect the aquatic ecosystem, and ecosystem components can be good indicators of mine-related effects. The purpose of baseline monitoring programs for the aquatic ecosystem is to develop a comprehensive understanding of baseline conditions for the aquatic ecosystem to support prediction of potential effects and evaluation of conditions and trends as the project proceeds.

The aquatic ecosystem is composed of both physical and biological components. Surface water quality, groundwater and hydrology are important components of the aquatic ecosystem. Baseline characterization requirements for these components are addressed in other sections. The baseline monitoring program for the aquatic ecosystem must be integrated with the surface-water quality and hydrology programs and must be designed to develop a comprehensive understanding of all key components, especially focusing on components that may be directly affected by the proposed project, or are good indicators of changes in water quality or flow. The scope of baseline programs for the aquatic ecosystem will depend on the specific project and ecosystem conditions, but usually include monitoring of at least sediment, benthic invertebrates, periphyton, fish and fish habitat. Other components (e.g., aquatic vegetation) must be included if appropriate.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

7.2 Data and analysis requirements

Integration and coordination of baseline monitoring programs for all components of the aquatic environment will help improve the strength of the data set for interpretation of site conditions, prediction of effects and evaluation of conditions once the project proceeds. Where possible, sites for data collection must be in the same locations for all components, and sampling events should be conducted at the same time when data are being collected for multiple components.

7.2.1 Sediment

Proponents must collect sufficient baseline sediment data to characterize spatial and annual variability in watercourses at the site; proponents are recommended to collect at least three years of consecutive data with sample collection occurring at times of the year when annual cycles of sediment accumulation are expected to be highest. The design of the program must consider future data interpretation requirements, and therefore include characterization of conditions in reference, project and receiving environment areas. Specific locations for sediment sampling must be in areas where sediment deposition occurs, rather than erosional areas of watercourses.

The sediment sampling program should focus on surface sediments as they are considered most ecologically relevant for interaction with other components of the aquatic ecosystem, and are the most recently deposited. Samples must be collected in conjunction with water quality sampling (field and lab parameters) to support data interpretation. Sediment samples must be analyzed for both physical (e.g., grain size) and chemical (e.g., pH, metals, total organic carbon) properties. Segregation and separate analysis of coarse and fine portions will be beneficial in many cases.

Concentrations of metals in sediment should be compared to the CCME *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.* If no CCME Guidelines are available, other guidelines that define a similar level of protection may be used. Rationale should be provided for using any other guidelines. If analysis indicates that some parameters exceed the probable effects levels, baseline sediment toxicity testing should be undertaken as part of the baseline program, especially for project and receiving environment areas.

Sediment sampling methods should be consistent with those described in *British Columbia Field Sampling Manual* (BC Ministry of Environment and Climate Change Strategy, 2013).

7.2.2 Benthic invertebrates

Benthic invertebrates can be good indicators of subtle changes in aquatic ecosystems, including changes arising from both contaminants and disturbance. They integrate effects associated with changes in both water and sediment. Proponents must collect sufficient baseline benthic invertebrate data to characterize spatial and annual variability in watercourses at the site; proponents are recommended to collect at least three years of consecutive data collection.

Benthic invertebrate monitoring and analysis programs must be designed to distinguish future mine-related changes from those associated with natural variability. To support this future requirement, the design of the program must include characterizations of conditions in future reference, project and receiving environment areas. Reference areas must be selected with similar habitat conditions, and sufficient reference areas must be included to understand natural variability. The number of required reference sites and the specific requirements for monitoring at each site will depend on program design. Both control-impact and reference condition approach must be considered when designing programs.

Sampling methods for benthic invertebrates should follow the Canadian Aquatic Biomonitoring Network (CABIN) sampling protocol (Environment Canada 2012). This protocol requires collection of supporting information along with benthic sampling, including details about each sampling location and stream characteristics (e.g., temperature, dissolved oxygen, pH, conductivity, water velocity, sample depth, stream width and depth, substrate characteristics and the type and relative coverage of any aquatic vegetation). Collection of water-quality and sediment samples at the same locations will also aid in data interpretation.

Benthic invertebrate samples require sorting and taxonomic identification by experts with appropriate certification through the taxonomic certification program of the society for freshwater science.

Various statistical methods can be used to analyze benthic invertebrate data. Baseline programs must present organism abundance, taxon richness and diversity, along with additional analyses that will help to identify future effects from mining activities. All endpoints must be reported with mean, median, minimum, maximum, standard deviation, standard error and sample size.

7.2.3 Periphyton

Periphyton are algae that grow attached to substrates and play an important role as a source of energy in stream ecosystems. Periphyton can be sensitive to physical habitat disturbance and changes in water quality, making them good indicators for mine-related effects. Proponents must collect sufficient baseline periphyton data to characterize spatial and annual variability in watercourses at the site; proponents are recommended to collect at least three years of consecutive data collection.

Periphyton monitoring programs must include characterization of conditions in future reference, project and receiving environment areas. This will provide data that can be used to interpret future monitoring results once the project is under development. Reference areas must be selected with habitat conditions that are similar to those in the project and receiving environment areas.

Periphyton sampling methods should be consistent with those described in *British Columbia Field Sampling Manual* (BC Ministry of Environment and Climate Change Strategy, 2013). Samples must be collected for both chlorophyll analysis and taxonomic identification. Periphyton sampling programs must be integrated with water-quality and sediment sampling to support data interpretation.

Periphyton samples require sorting and taxonomic identification by appropriately trained experts. Various statistical methods can be used to analyze periphyton data. Baseline programs must present information on density, diversity and additional analyses that will help to identify future effects from mining activities. All endpoints must be reported with mean, median, minimum, maximum, standard deviation, standard error and sample size.

7.2.4 Fish and fish habitat

Contaminants and disturbance associated with mining can affect fish populations and fish health. Many of the impacts of mine development on fish arise due to impacts on their habitat. These impacts include alteration to sediment deposition and scour processes in streams, sediment accumulation in lakes and wetlands, stream crossings (roads, pipelines, and power lines), stream diversions, changes to stream flows, effluent discharge and complete habitat loss within the project footprint. In addition to these habitat-related effects, effluent discharge can have direct impacts on fish health. A baseline program for fish and fish habitat needs to provide data to develop a thorough understanding of current fish populations, health and habitat, including annual and seasonal variability. The program must be designed to support evaluation of future conditions to determine whether the project is causing adverse effects, for example increased stress, disease, mortality, decreased growth, inability to reproduce, survival, recruitment and production. Baseline programs must provide at least three years of fish and fish habitat data. Baseline data collection must capture detailed information in areas that will be affected by the project, and also in relevant reference areas that will not be affected.

Fish and fish habitat monitoring programs must include the following components:

- Abundance, distribution and migration of fish in the project area during all seasons and for all life stages. Various methods may be used to gather data about abundance, distribution and migration, including angling, seining, minnow traps and electrofishing. Methods must be selected based on site conditions, target species, life stage and practicality. A range of methods must be applied where possible, especially where multiple species and life stages may be present. Telemetry programs must be considered where substantial changes in habitat conditions are expected.

- Fish habitat surveys, focusing on areas that are used during important life stages including, for example, spawning, rearing and over-wintering. Habitat surveys must include stream morphology, riparian vegetation, aquatic vegetation, cover, habitat types and sediment transport conditions. Collection of water quality and sediment samples and flow data during periods of fish use will help with data interpretation.
- Evaluation of health of fish and fish populations including data about size, life stage, condition and age.
- Collection of tissue samples and analysis for concentrations of contaminants of concern, including metals.

Understanding the condition of fish populations requires information about other ongoing activities that may cause their own effects, for example pressures due to harvesting. A baseline program must include characterization of these external pressures to provide context for interpretation of any future changes in fish populations and health.

Overall, the nature and extent of baseline data requirements will depend on the fish populations and species in question and the anticipated impacts of the project on aquatic ecosystems. The purpose is to fully understand the fish and fish habitat values to be impacted locally and be able to consider these impacts in the context of the wider landscape and population circumstances. As a result, information requirements for review may change in response to initial baseline data. Regular submission of work plans and interim study reports to regulatory agencies during the pre-application stage is an important component of scoping the extent of data requirements for quartz mining projects

8 Climate change

The following section provides guidance on what needs to be considered and documented in applications when characterizing the observed climate. The approach to developing a climate baseline that is appropriate for all stages of mine life is based on guidance accepted by the World Meteorological Organization (WMO) and other scientific bodies. The guidance focuses on observed climate specific to the Yukon with references to indices that can be used to complement the baseline climate dataset. The baseline information gathered based on the requirements outlined in other sections of this document are to be used to develop a robust climate baseline and to inform the characterization of the observed climate.

8.1 Data selection criteria

Proponents must document their understanding of the historical and current climate and trends in order to develop design parameters. Where available, observed climate data from meteorological stations are typically used to define the climate baseline. The analysis of observed climate is required to identify the climate variables that can affect the design or maintenance of mine infrastructure.

When identifying a meteorological station which best represents a mine site's climate, the following selection criteria must be considered:

- the length of record (minimum of 20 years, ideally 30 years of data);
- availability of a continuous record (e.g., no consistent missing days, months or seasons);
- proximity to the area of interest;
- age of observations compared to the currently accepted normal period;
- latitude;
- elevation of station;
- geographic siting; and
- monthly data availability threshold of 90% valid data for all years.

The available climate data from each station must be compared to, and meet, the selection criteria outlined above for the climate baseline period. Data from many weather stations can be constrained by low numbers of observations or a limited lifespan for the station (data quantity) and varying data quality. Therefore, the station which matches the most criteria, with the first three criteria bearing the most weight, should be identified and a rationale for using this station provided along with any limitations in the data. If a 30-year baseline period is not possible, then the minimum duration can be taken as 20 years; however, any duration less than this may result in projections that are opposite to the long-term trends due to short-term variability.

Ideally, observed climate should be characterized based on available long-term daily meteorological observations from a station either on-site or close in proximity with similar geographic/climatic influences as the mine. Proximity to geographical features which may influence site climate and meteorological station selection must be carefully considered for each site. For example, if a mine is located next to a large body of water then the most representative station should not only be close to the same body of water, but should also consider where the station is in relation to the body of water (e.g. effects of prevailing winds across the water body). Based on available data sources, continuous long-term on-site weather station data is always preferred to best capture local influences.

To establish a climate baseline, the observations must be long enough to adequately characterize the long-term climatic conditions and not be overly influenced by short-term variability. A short-term average may be influenced by irregular warming or cooling trends; therefore, climate baselines are required to be averaged over a longer period of time (20-30 years) (Charron 2016). In addition, it is important to be aware of events that have occurred in the historical record such as extreme precipitation events. For example, a longer historical period (greater than 30 years) will capture a large variety of storm events for characterizing maximum precipitation, but the most recent observations (~30 years) are preferred when establishing temperature trends. Accurate documentation of the selected meteorological stations and time period of available observations is a necessity for any baseline climate analysis.

The meteorological observations should be considered from stations that have quality assurance and management of observing systems according to best guidance provided by Part III in *Guide to Meteorological Instruments and Methods of Observation* (WMO 2008). Publicly available data sources for current climate are listed and described in Table 7.

Table 1: Observed climate data sources specific to the Yukon

Name of data source	Description
National climate data and information archive (Government of Canada, 2019)	Provides historical climate data from present and past weather stations throughout Canada. Observations are available from hourly to monthly resolutions for temperature, precipitation and wind-related variables. Available at: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
Climatedata.ca (ECCC, Ouranos, CRIM, PCIC, Prairie Climate Centre, Habitat Seven)	Online climate data portal allows users to search for climate data by location, view climate normals in chart format and download historical climate data. Observations are available at the daily time-scale and include all variables in the station record. Historical IDF curves are provided for select stations. Available at: https://climatedata.ca/
Engineering climate datasets (Government of Canada 2019b)	Provides historical engineering climate datasets from present and past weather stations throughout Canada. Includes IDF curves, Canadian Weather Energy and Engineering Datasets (CWEEDS), and Canadian Weather Year for Energy Calculation (CWEC). Available at: http://climate.weather.gc.ca/prods_servs/engineering_e.html

8.1.1 Infilling missing data

If available station data does not meet the selection criteria listed above, options are available to fill data gaps, which can include using multiple station data or reanalysis data.

Reanalysis data can be used to infill missing data from a representative station by integrating it with climate observations from a specific area with the caveat that the reanalysis data may not capture local conditions or influences. A bias correction can be completed to improve the representation of local conditions through a correlation analysis with available weather station observations. Available resources for reanalysis data can be found from the North American Regional Reanalysis (NARR), the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2), and the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA5) databases. It should be noted that in areas where observations are limited, reanalysis data may be less robust, as reanalysis data assimilates observational data if available. Reanalysis datasets should be evaluated to assess which dataset best represents the site climate.

Data from multiple stations can be used in instances where the elevation of the mine of interest does not match the most representative station data. As temperature and precipitation vary with elevation, adjustment factors determined from the multiple station data can be applied to create an enhanced representative dataset for elevation of the mine of interest.

8.2 Quantifying climate baseline, extremes and trends

When selecting a source of climate data for the current climate period, an understanding of the climate information is necessary to gather the relevant data to determine a climate baseline. It is recommended to consider the following (Charron 2016):

- Why is the climate information needed?
- What climate variables are of interest?
- What temporal and spatial resolutions are required?
- What area does the information cover (e.g. local or regional)?
- What climate statistics (e.g. mean or extreme) are of interest?

The climate normals and trends must be calculated using the selected station data (or infilled station data) for the chosen baseline period (consider covering the climate normal and ideally extending to the most recent observations). Station data, gridded and or modelled data may all be useful in establishing climate trends for a site. When calculating the annual and monthly climate normals and trends, mean temperature and total precipitation must be considered as described below:

- Total precipitation (mm): the sum of all observed total precipitation during the selected annual period. Each annual value is averaged over the period of the climate normal.
- Monthly precipitation (mm): the sum of all observed total precipitation during a month in an annual period. Each monthly value is averaged over the period of the climate normal.

- Average annual temperature (°C): the average of all observed daily mean temperatures for selected annual period. Each annual value is averaged over the period of the climate normal.
- Monthly temperature (°C): the average of all the observed mean temperatures during the selected month in an annual period. Each monthly value is averaged over the period of the climate normal.

In addition to the annual and monthly current climate parameters discussed above, climate extremes will also need to be evaluated. Climate extremes pose risks for a mine at all phases of its life cycle, influencing the planning, design, operation, closure and post-closure. For example, climate extremes such as heavy precipitation events can impact infrastructure and interrupt operations due to resulting flooding or inability to deal with the excess water as part of the existing water-management plan. Climate extremes must also be considered when developing design parameters, especially any climate extremes that have been previously experienced (e.g. intense storm events).

The WMO provides a set of 27 climate indices which can be used to characterize climate extremes which must be calculated and compared for the observed and future climate (WMO 2009). These indices include extreme climate statistics such as the number of hot and cold days, length of growing season, wet and dry day frequencies, days with heavy precipitation, etc. These indices must be used as a starting point for the evaluation of climate extremes for the mine and other indices must be developed as required.

8.3 Quantifying observed permafrost

Mines located in Arctic regions may consist of infrastructure that relies on permafrost or are vulnerable to degradation of the permafrost. The structural integrity of infrastructure such as tailings ponds, access roads, haul roads, building foundations, engineered covers and other subsurface structures can be compromised due to increase in the active layer of the permafrost. Developing a baseline for permafrost in the Yukon can be beneficial for mine sites in these regions with vulnerable infrastructure. Publicly available sources listed in Table 2 provide information on current permafrost extent, the classification and depth.

Table 2: Current and historical permafrost data sources

Name of data source	Description[1]
Yukon permafrost database	A compilation of ground thermal and geotechnical data in Yukon, including related reports. Available at: https://service.yukon.ca/permafrost/
Global Terrestrial Network for Permafrost (GTN-P)	Includes permafrost monitoring observations for permafrost extent and classification in the Arctic and sub-Arctic regions. Provides limited historical data for boreholes in the Yukon. Available at: http://gtnpdatabase.org/sites/view/73/#.XoNnxohKjcu
National Snow and Ice Data Center (NSIDC)	The centre provides data for many regions, with variables specific to the cryosphere, including permafrost thickness, active layer, air temperature and snow depth. Available at: https://nsidc.org/data/GGD318
Geological Survey of Canada (GSC)	Provides archives of Canadian geospatial information, including maps on Canadian permafrost thickness. Available at: https://www.nrcan.gc.ca/science-and-data/science-and-research/earth-sciences/geography/topographic-information/download-directory-documentation/17215
Permafrost Information Network (PIN)	Provides a visualization map of permafrost related information, including permafrost boreholes, surficial geology, and bedrock geology from Natural Resources Canada. Available at: https://gin.gw-info.net/service/api_ngwds:pin/en/wmc/pin.html

[1] Links provided to the selected data sources were available at the time of the release of the report.

8.4 Quantifying observed precipitation and rainfall

Changing precipitation patterns are a concern for quartz mining as it changes when, what type, and how much water the mine must manage. Precipitation patterns may evolve over the climate baseline and may differ from the historical or current data used to develop the climatic assumptions applied in mine infrastructure design. Proponents must consider changing precipitation patterns through quantifying precipitation variables that are appropriate to the mine plan such as:

- Probable maximum precipitation (PMP) or Probable maximum flood (PMF);
- Intensity-duration-frequency (IDF) curves and rainfall statistics (annual and monthly distributions);
- snowpack and snowmelt; and
- evapotranspiration and/or evaporation.

Probable maximum precipitation (PMP) is defined as "the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends" (WMO 2009). The PMP is a theoretical value that represents the greatest amount of rain possible in a given area, as opposed to a design storm that represents the amount of rain associated with a specific probability of occurrence. The WMO acknowledges that there is significant uncertainty regarding PMP calculations and recommends that a comparison of reported values is conducted. There are two widely accepted approaches (meteorological and statistical) to estimate the PMP. The meteorological approach compares measured rainfalls against measured and maximum moisture content or precipitable water while the statistical approach uses the statistics of historical annual maximum rainfall events to estimate the PMP.

The probable maximum flood (PMF) is defined as "the theoretical maximum flood that poses extremely serious threats to the flood control of a given project in a design watershed. Such a flood could plausibly occur in a locality at a particular time of year under current meteorological conditions" (WMO 2009). PMF can be obtained from the PMP through a series of hydrologic transformations using simple to complex hydrological modelling. Hydrological modelling is needed to capture how a PMP event translates into runoff through a watershed, potentially impacting water management. The critical duration, flood peak and flood volume are important considerations when estimating PMF. The approach to estimating PMF will vary based on the size of the watershed and characteristics of the site, but a general overview of the steps is available from WMO (2009).

Extreme rainfall events for a range of durations and return periods must be calculated using rainfall statistics. The results are published as intensity-duration-frequency or IDF curves. There are multiple methods available to estimate IDF curves including the method of moments to estimate parameters for the Gumbel distribution based on 1-day duration rainfall events for selected return periods to estimate the daily duration IDF curves and rainfall statistics, similar to ECCC's methodology at select monitoring stations. When referring to daily IDF curves and rainfall statistics it should be clear whether the duration is 24-hour (based on hourly observations) or 1-day (based on hourly or daily observations). The 24-hour rainfall is calculated as the maximum rainfall during a moving block of 24 hours while the 1-day rainfall is calculated as the maximum rainfall during a fixed period (typically from midnight of one day to midnight of the next). Due to the differences in the method of calculation, there are typically differences in the values, with the 24-hour rainfall often being higher (since the moving block allows for greater capture of storms). CSA (2019) provides guidelines for the development, interpretation, and use of IDF curves in Canada for water resource practitioners under current and future climate conditions. The methods described within this document must be used in the development of a climate assessment as it represents the most recent and definitive guidelines on IDF curves in Canada.

Sub-daily IDF curves and rainfall statistics can be estimated using hourly observations if available. Sub-daily running totals for precipitation for the desired durations (1-hour to 24-hour) are derived and then a similar methodology to the daily IDF curves and statistics can be applied. Multi-day IDF curves and rainfall statistics can be estimated using hourly or daily observations by deriving multi-day running totals for precipitation for the desired durations (e.g., 2-day to 120-day) and then applying the same methodology as for the daily duration. Additionally, ECCC provides sub-daily IDF curves at some weather stations for selected return periods.

Unlike rainfall, snowfall does not necessarily produce an immediate effect. An individual snowfall may be smaller than a rainfall event (based on equivalent depth of water), but snowfall can accumulate into snowpack. Melting of snowpack can occur simultaneously with rainfall events, thus producing additional runoff at the site. For longer event durations, the combined effect of rainfall and snowmelt may be significantly greater than that of only precipitation. Proponents are therefore required to estimate the probability of large snowpack to occur and associated melt events. Where snowpack is measured, this can be done in a similar fashion to the IDF curves (using maximum annual values for snowpack and snowmelt fitted to Gumbel distributions); where snowpack is not measured, estimates of snow accumulation and melt based on precipitation and temperature (Louie et al. 1980) must be used to obtain annual maximum values for snowpack and snowmelt.

Evapotranspiration refers to the loss of moisture from a vegetated surface. Rates of evapotranspiration affect the water balance of the site, as well as the storage potential for subsequent rainfall events. It is affected by the energy input to the vegetated surface (air temperature and solar radiation), and how efficiently moisture can be transferred (humidity and windspeed). The relative importance for each of these variables to affect evapotranspiration rates varies based on site climate. For many locations, observations of solar radiation, humidity and wind speed may not be available. Methods are available to estimate evapotranspiration based on air temperature alone, such as the Hargreaves equation (Food and Agriculture Organization [FAO], 2006) and the Thornthwaite Equation (Thornthwaite, C.W.1983). Proponents must include an assessment of the significance of evaporation and evapotranspiration to the mine and include an appropriate estimated value.

9 Terrestrial ecosystem and resources

9.1 Purpose and scope

Mining projects can affect terrestrial ecosystems and resources by a variety of pathways. Within the mine footprint, activities cause direct disturbance of land, vegetation and wildlife. Transport of contaminants via air and water can lead to increased contaminant concentrations in the terrestrial ecosystem. The purpose of baseline monitoring programs for the terrestrial ecosystem is to develop a comprehensive understanding of baseline conditions for the terrestrial ecosystem to support prediction of potential effects, development of appropriate reclamation plans and evaluation of conditions and trends as the project proceeds.

The terrestrial ecosystem is composed of both physical and biological components – soils as well as plants and wildlife. Baseline characterization needs to address all of these components and will need to be integrated with aquatic monitoring programs where it is important to understand the interactions between aquatic and terrestrial ecosystem components, for example in wetlands. Characterization of wildlife habitat is a key output of the terrestrial ecosystem monitoring program and will rely on the data collected about all terrestrial ecosystem components. The scope of baseline programs for the terrestrial ecosystem will depend on the specific project and ecosystem conditions, but will usually include the following:

- soil physical properties and nutrients, especially with respect to performance for reclamation;
- background soil contaminant concentrations;
- vegetation surveys;
- rare plant surveys;
- vegetation contaminant concentrations;
- wildlife surveys;
- wildlife habitat assessments; and
- wildlife contaminant concentrations.

It is important to collect the most accurate baseline data possible using accepted or standardized practices and procedures. Before beginning a monitoring program for a proposed development, the proponent should contact the Yukon government to discuss the type and amount of data required.

First Nations and communities often have a keen interest in potential effects on both vegetation and wildlife, especially if the project is in a harvest area. The development of sampling programs for vegetation and wildlife must include processes for seeking and incorporating input from First Nations and local communities about species and locations for sampling. Direct participation of First Nations and local communities in sampling programs is encouraged.

9.2 Vegetation and surface soils

A comprehensive understanding of vegetation associations and groups and surface soils will be needed to support reclamation planning, helping to define reclamation objectives and facilitate the selection of suitable reclamation seed/stock. Understanding existing vegetation communities and contaminant concentrations in vegetation and soils will be needed to support prediction of project effects and confirmation of project performance.

Design of vegetation baseline monitoring programs must begin by defining appropriate study areas. Often, these programs will consider both local and regional study areas, where survey intensity may be greater in local study areas. Local study areas must include areas where there is the potential for direct or indirect effects from the project. Regional study areas usually cover a wider area, where effects of the project may still be measurable and their significance may be linked to cumulative effects. The establishment of vegetation study areas must consider the information requirements for understanding wildlife habitat.

Vegetation and soil surveys must be conducted to support ecological land classification for a study area that includes areas potentially affected by mining activities and appropriate reference areas. This must include areas that may be affected by access roads, and any other accessory activity in relation to the mine (e.g., power lines). Surveys must address any sensitive habitats, for example wetlands or high-value forage habitat for caribou. Data for local study areas should be consistent with the methodologies and approaches described in the *Yukon Ecological & Landscape Classification Program* documents for the area where the project is occurring. In some cases, less intensive surveys may be warranted for large regional study areas. Descriptions must be of sufficient quality that a key habitat assessment for important wildlife species in the area can be conducted. Rare plant surveys must be completed in areas that will be subject to physical disturbance by mine-related activities. The purpose of these surveys is to identify the presence of any species at risk as identified by the federal Committee on the Status of Endangered Wildlife in Canada or listed by the Yukon government as conservation concern by the Yukon Conservation Data Centre.

Programs to characterize baseline concentrations of contaminants in surface soils and vegetation are required. The program should be designed to characterize conditions in areas affected by the project (e.g., project footprint and airscape) and appropriate reference areas. Soil samples from throughout the soil profile must be collected at the same locations and times as vegetation samples to develop an understanding of any relationships between concentrations in parent materials and vegetation, and the relationship of contaminants through the soil profile.

9.3 Wildlife and wildlife habitat

Wildlife baseline monitoring programs provide a basis for predicting potential project effects on ecosystem components that are usually of significant importance for First Nations and local communities. First Nation final agreements provide harvest rights that can be affected by changes in abundance and distribution of wildlife. The baseline programs will support design of mitigation approaches intended to minimize adverse effects on wildlife. In many cases, baseline programs also need to characterize contaminant concentrations in local fish and wildlife for comparison with future conditions.

Design of wildlife baseline monitoring programs must begin by defining appropriate study areas. Wildlife monitoring programs often consider both local and regional study areas. Local study areas must include areas that are directly affected by the project, where the focus of monitoring may be on species that spend their whole life in the study area or migrate through. These local study areas need to include areas affected by access roads. These roads can have significant effects on wildlife due to direct mortality from traffic. Regional study areas usually cover a wider area and consider effects on more mobile species. The definition of study areas may need to consider the results of vegetation and soil surveys to identify areas of critical habitat that must be included in either local or regional study areas.

Government agencies collect a variety of wildlife related data that must be identified and incorporated into the design and interpretation of wildlife baseline programs, for example:

- Yukon government wildlife key area datasets;
- Environment Canada breeding bird survey;
- Yukon government data collected under the Yukon hunting regulations;
- Information about species at risk – e.g., Yukon conservation data centre, species at risk act registry, NatureServe Canada, Committee on the Status of Endangered Wildlife in Canada; and
- Results of local or regional government studies or surveys.

Wildlife surveys must provide an understanding of species abundance and distribution within the study areas, considering year-round, seasonal and transient uses. Surveys must support identification of any important habitat areas and the development of appropriate mitigation measures. The surveys, in combination with habitat assessments, must also provide sufficient information to support the definition of future reclamation conditions. Surveys must include wildlife species that fill a range of ecological niches and that will be good indicators of project effects. Surveys must include species that are identified as important values from various perspectives, including First Nations, communities, ecological significance, and also those that are at risk or of conservation concern. At a minimum, the following groups of species must be addressed in the baseline program:

- ungulates (e.g., moose, caribou, sheep);
- bears;
- furbearer species;
- avian species (e.g., waterbirds, passerines, raptors, upland game birds); and
- invertebrates.

Various methods can be used to collect wildlife data, for example aerial surveys, ground surveys, tracking surveys and remote cameras. Methods will depend on species of interest, site conditions, habitat types and seasons. Proponents should engage skilled wildlife survey experts to design and implement wildlife baseline programs. In all cases, proponents must maintain a wildlife log at the site and record incidental wildlife sightings.

Understanding the condition of wildlife populations requires information about other ongoing activities that may cause their own effects, for example pressures due to harvesting and other human activities. A baseline program must include characterization of these external pressures to provide context for interpretation of any future changes in wildlife populations, habitat and health.

Wildlife survey results, in combination with data from other sources, must be used to develop the following as part of a baseline characterization:

- describe abundance and distribution characteristics of wildlife species within the project area and vicinity;
- describe the habitat classifications used in the project area, and any implications concerning the distribution and abundance of habitat types that may influence the project;
- provide a map showing habitats of special interest or high value, if applicable;
- identify and describe travel corridors and critical, key and sensitive habitats;
- include periods of habitat use in the project area and vicinity;
- identify any species listed on the Committee on the Status of Endangered Wildlife in Canada and Species at Risk lists;
- describe any special management requirements due to vulnerability, threatened or endangered status;
- describe potential for any adverse effects on wildlife values and planned actions to mitigate effects; and
- identify and describe any ongoing studies and monitoring programs with respect to wildlife in the project area and vicinity.

Programs to characterize baseline concentrations of contaminants in wildlife must be completed in areas that will be directly affected by mining activities and in appropriate reference areas that will not be affected. In many cases, direct measurements of contaminant concentrations will focus on small mammals that spend their entire life in localized areas. Such species can provide valuable information about contaminant migration in the terrestrial ecosystem. Sampling of small mammals must be coordinated with sampling of soils and vegetation to improve data interpretation.

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Appendix B
Site Characterization

February 2023

Yukon

Executive summary

The purpose of this document is to inform proponents early in the mine planning process of the site characterization information that the Yukon government expects to be provided during environmental assessment and permitting processes for quartz mining projects.

It is essential that proponents undertaking advanced mineral exploration read this document and meet with the Yukon government to obtain advice on characterization requirements as early in the exploration program as possible. The different components of any study conducted should be planned and conducted by a qualified professional in the relevant field.

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1. Introduction

The design of mine waste management facilities requires detailed site characterization; data collected for baseline characterization purposes, as described in Appendix A, will contribute to site characterization for design purposes. This appendix describes expectations for additional detail that will be needed to adequately understand specific site conditions to support design analysis for facilities and structures.

2. Water balance

A water balance of the entire site, including any water retaining structures as well as any mine workings and other associated infrastructure, must be quantified as part of the water quality and quantity management activities at a mine site. The studies must be completed to:

- establish hydrogeological parameters governing flow of surface and groundwater at the site;
- establish factors to characterize the behaviour of contaminant transport at site, including hydrogeological parameters and the anticipated type/location/quantity of contaminants that will be present on site;
- predict the changes to the site and downgradient surface and groundwater hydrology as a result of proposed site development (e.g. water consumption, changing drainage/infiltration patterns, etc.);
- evaluate strategies for optimum use of limited water supplies;
- establish procedures for limiting site discharge and complying with discharge requirements – in particular the control of the quality of the water and the quantity of contaminants discharged from the site;
- limit or control erosion due to flow over exposed surfaces or in channels, swales, and creeks; and,
- estimate the demands on water treatment plants, holding ponds, evaporation ponds or wetlands.

The water balance must include detailed descriptions of the existing surface and ground water bodies at the mine site and the measures to be taken for their protection, including control of erosion, sedimentation, siltation, water treatment, diversion of watercourses and measures for protection of contamination of ground water. A hydrological study carried out in the area must also be included. A graphical presentation of the water balance chart must be provided. If there is potential for metal leaching/acid rock drainage or metal leaching, then the mitigation method must also be provided.

It is noted that there are as many types of water balance studies as there are types of mines and stages of mining. For a given project, studies must be completed to assess the site water balance at the following phases of the project life:

- Planning Phase/Development Phase – pre-mining prediction, evaluation, and design
- Operations Phase – mine operation modeling and control
- Closure Phase – closure planning and design, post-closure maintenance

Normally, commercially available software is used to build a water balance model of a site.

Before starting a water balance study, it is important to have good information about the site and facility layout.

This includes quantification of area, topography, climate, runoff, slopes, location and condition of streams and constructed channels, and the location and configuration of the mine workings, if applicable. The data must include digital maps that may be used with CADD or GIS systems.

Flow and channel cross-section information must be collected from streams and rivers that enter and exit the site. Hydrometric stations should be installed in representative stream and river locations.

3. Geochemical characterization

The geology and ML/ARD characterization beyond the actual ore body needs to be sufficient to characterize the variability of the materials to be disturbed. The characterization must also be extensive enough to accommodate various mining scenarios (e.g. pit expansion or wall push-back for geotechnical concerns).

Geochemical characterization must be carried out on all materials being disturbed or impacted and should also be carried out on the periphery of ore bodies to support future development.

Proponents are encouraged to follow the methodologies presented in Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1 when finalizing field programs for data collection. Cold weather impacts need to be taken into account when developing field programs and determining the acid generation, neutralization or metal leaching potential of disturbed material.

3.1. Heap leach ore

Heap leach ore geochemical characterization should include the following:

- detailed description of the geochemistry of the ore materials both as mined and after processing on the leach pad;
- ore and drainage layer permeability test work;
- results from mineralogy, acid-base accounting, shake flask tests, kinetic testing and column leach tests;
- results for leaching, rinsing, detoxification and neutralization test work, including details of expected water chemistry for each stage;
- contaminants of concern for the project, with rationales for the inclusions and exclusions;
- projections of water quality associated with the ore materials during mine operations, heap rinsing, heap detoxification and post-closure; and
- appropriate contaminant loading models to demonstrate how the ore materials will interact with the surrounding aquatic environment, in combination with effects from other mine components.

3.2. Waste rock and overburden

Waste rock and overburden geochemical characterization should include the following:

- detailed description of the geochemistry of the rock and overburden materials;
- results from different units that are suitable for construction purposes use, and the constraints for their use;
- results from mineralogy, acid-base accounting, shake flask tests, humidity cells and other test programs;
- projections of water quality associated with the rock and overburden materials; and
- descriptions of the expected pore water and seepage water quality and how it is expected to fluctuate throughout the life of the project.

3.3. Tailings

Tailings geochemical characterization should include the following:

- detailed description of the geochemistry of the tailings;
- results from mineralogy, acid-base accounting, shake flask tests, kinetic testing, aging tests and other test programs. These results should be from tailings produced from a laboratory program that is representative of the planned processing approach for the project. For an expansion of an existing project, the as-produced tailings from existing processing may be used to the extent they represent the proposed tailings. Rationale must be provided.
- contaminants of concern for the project and provide rationales for the inclusions and exclusions;
- projections of water quality associated with the tailings materials;
- description of the supernatant water, pore water, runoff, seepage and groundwater chemistries and how these will fluctuate through the life of the project; and
- contaminant loading models to demonstrate how the tailings will interact with the surrounding aquatic environment, in combination with effects from other mine components.

4. Geotechnical characterization

4.1. Mine waste management facilities

Geotechnical characterization for a tailings management facility, heap leach facility and mine rock management facility should include the following:

- information about surface and subsurface conditions, including geology of the area, geomorphic features and bedrock composition;
- description of the overburden materials, including material types, properties and layering;
- description of the thermal conditions including depth, extent, ice content and temperature profile of any permafrost; and
- depths to bedrock and characteristics of bedrock, including strength and permeability of each stratum.

Data from geotechnical testing and site investigations programs, including borehole and test pit logs and testing results (e.g. specific gravity, gradation, consolidation, bulk density, plasticity and moisture content). For geotechnical site characterization, site investigations must at least conform to guidelines issued by the Association of Professional Engineers and Geoscientists of British Columbia.

4.2. Overburden materials

The types of characterization tests for overburden materials include the following:

- soil types and distribution across the site (Protocol 3 and 9 of the Yukon Contaminated Sites Regulation);
- distribution and thickness of organic/peat deposits and ice-rich materials;
- depth to groundwater (Protocol 7 of the Yukon Contaminated Sites Regulation);
- inorganic soil density and consistency using field methods (SPT, CPT, or vane shear);
- moisture contents (ASTM D2216);
- particle size;
- plasticity (ASTM D4318);

- liquefaction potential (in-situ strength testing);
- permeability (field constant head test in boreholes or testpits);
- shear strength/cohesion/frictional strength (triaxial or direct shear laboratory testing); and
- compressibility (triaxial or consolidation testing in laboratory).

4.3. Bedrock materials

The types of characterization tests for bedrock materials include the following:

- cyclic testing if applicable;
- geological history and existing bedrock mapping/rock classification;
- structural geology of the area;
- depth to competent bedrock across the site;
- thickness of weathered zone;
- depth to groundwater (install at least three groundwater monitoring wells in bedrock, if necessary);
- oriented rock core to determine fault/joint orientation relative to orientation of the structure being designed;
- Rock quality design (RQD) for rock core;
- laboratory unconfined compressive strength or point load testing; and
- deformation modulus.

4.4. Permafrost

The types of characterization tests for permafrost include the following:

- National Resource Council Canada (NRC) Ground Ice Classification System as shown in Figure 4-1;
- distribution in both overburden and bedrock;
- ground ice content in both overburden and bedrock;
- ground temperature (install several multi-bead thermistor cables) to obtain a ground temperature profile and active layer thickness; and
- pore water salinity.

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION
N	Nf	Poorly-bonded or friable
	Nbn	No excess ice, well-bonded
	Nbe	Excess ice, well-bonded

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION
V	Vx	Individual ice crystals or inclusions
	Vc	Ice coatings on particles
	Vr	Random or irregularly oriented ice formations
	Vs	Stratified or distinctly oriented ice formations

VISIBLE ICE GREATER THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION
ICE	ICE + Soil Type	Ice with soil inclusions
	ICE	Ice without soil inclusions (greater than 25 mm thick

NOTES:

1. Dual symbols are used to indicate borderline or mixed ice classifications.
2. Visual estimates of ice contents indicated on borehole logs ± 5%
3. This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes.

LEGEND: Soil ☐ Ice ■

Figure B- 1 NRC ground ice classification system

4.5. Terrain hazards

The types of characterization tests for terrain hazards include the following:

- landslide mapping;
- rockslide mapping; and
- avalanche path mapping

The proponents guide entitled Geohazards and Risk: Linear Infrastructure published by the Yukon Environmental and Socio-economic Assessment Board provides additional information that should be considered when characterizing terrain hazards.

5. Seismic considerations

Relevant earthquake monitoring locations should be located and historical data collected. For sites with Class III structures, a local monitoring station should be established if there are no adjacent monitoring stations.

Describe seismic hazard conditions for the project site, including supporting analyses. Perform probabilistic site hazard assessment (PSHA) and provide analyses for various return-period and deterministic (e.g. maximum credible earthquake) seismic events.

6. Construction materials

Potential construction materials (soil, aggregate, bedrock) should be located and generally defined with respect to quality, quantity and ease of access and production/excavation. The assessment of construction materials should must also include durability testing under repeated freeze-thaw and wet-dry cycles (slaking tests).

7. Contaminated sites considerations

Human health and ecological risk assessments (HHERA) are used on mine sites to evaluate whether contamination at a specific site poses acceptable or unacceptable risks to human health or the environment. The results of the HHERA will be used to inform final closure objectives for each component of a mine site and whether additional measures are required to mitigate potential risks.

A risk assessment should be compared to future land use of the mine site. This may include identified uses in local area plans or through consultation with affected First Nations and communities.

The problem formulation for a HHERA must be completed and included in assessment and regulatory application. The data collected throughout the life of the project will be used to support completion of a HHERA that must be part of the detailed reclamation and closure plan.

8. References

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Appendix C
Description of Design Levels

February 2023

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1. Objectives

The objective of this appendix is to describe the level of detail expected in the facility designs submitted for comment and approval during the various phases of mine planning including: environmental assessment, permitting, detailed design and construction.

The levels of detail include requirements for cost-estimating accuracy, the design analyses and drawings and the underlying information base that must be provided. In some instances, assessors or regulators may require increased levels of design for components of a Class III facility as more critical and more detailed designs are required. Section 2.2 of the main document describes the facility classification system for mine waste management facilities.

2. Design levels

Throughout the project planning, environmental assessment, permitting, design and construction phases of a mine project increasing levels of detail are required for the various mine components. These design levels range from conceptual design used for planning, through detailed design used for construction purposes, to as-built design required to record how components were actually constructed.

Table C-1 describes the various design levels and lists the following:

- the purpose the design would be used for (e.g. comparative analyses of options, regulatory approvals, construction, etc.);
- the percent complete each design level would attain. This percentage is based on the amount of engineering effort spent on the design with the construction designs being 100% complete. These percentages can be used to gauge the amount of effort needed for each design level;
- the likely cost estimate accuracy that could be achieved for each design level;
- the general requirements for each design level, and the information sources generally needed to complete designs at each level; and

- the climate data requirements expected at each level of design, and phase of mine life.

The design levels generally required include:

- conceptual;
- pre-feasibility;
- feasibility;
- preliminary;
- detailed; and
- as-built.

Specific levels of design that have to be achieved are also described in the relevant sections of the main document.

Table C- 1 Design levels

TABLE C-1 – DESIGN LEVELS						
ATTRIBUTES	**CONCEPTUAL**	**PRE-FEASIBILITY**	**FEASIBILITY**	**PRELIMINARY**	**DETAILED**	**AS-BUILTS**
Purpose	Screening of options in options assessments. Required for selecting preferred options, preliminary assessments of effects associated with the facility, and completing comparative risk assessments.	Required to select the preferred option for a facility that will be included in the mine plan and subject to assessment and regulatory approvals.	Required for environmental assessment applications to the Yukon Environmental and Socio-economic Assessment Board.	Required for obtaining regulatory approvals – quartz mining license and water use licence applications.	Required prior to construction of any facility for review and approval. As-built reports must be summited to regulators within the licensed time limits.	Required for record keeping.
Percent completion[1]	5% to 10%	10% to 30%	30% to 60%	60% to 80%	95% to 100%	
Construction cost estimating accuracy	+/- 50%	+/- 25%	+/- 20%	+/- 15%	+/- 10%	N/A
Design and planning requirements	**Design analyses** • Construction quantity calculations • Waste volume and water storage calculations • Construction material sources and approximate volumes **Drawings** • General site layout • Facilities plans and sections showing all major dimensions	**Design analyses** • Establishment of design criteria (geotechnical, seismic, water management) • Refinements to the conceptual/scoping level analyses • Preliminary foundation and slope stability calculations for major elements • Preliminary monthly water balance and seepage calculations for average and extreme wet and dry years • Preliminary water quality analyses	Refinement of pre-feasibility design analyses and designs; incorporation of survey data on drawings, including preparation of detailed construction specifications.	Refinement of feasibility design analyses and designs; incorporation of survey data on drawings, including preparation of: • detailed construction specifications; • detailed construction schedule; and • execution plan.	Refinement of preliminary design analyses and designs; incorporation of survey data on drawings, including preparation of: • detailed QA/QC manual; and • detailed OMS manual.	As-built report including the results of the QA/QC program and the as-built drawings and construction photographs.

[1] The percent complete can be expressed as a relative level of effort, such as person-hours, compared to the level of effort to complete the construction design and as-built drawings and reports.

TABLE C-1 – DESIGN LEVELS						
ATTRIBUTES	**CONCEPTUAL**	**PRE-FEASIBILITY**	**FEASIBILITY**	**PRELIMINARY**	**DETAILED**	**AS-BUILTS**
	• Contact and non-contact water management facilities layouts • Roads and ditch alignments • Foundation concepts **Description of other features, as applicable** • Conceptual closure plan • Conceptual closure options • ARD/ML management facilities	**Drawings** • Refinement of conceptual/scoping designs based on site-specific data and additional analyses; in addition to provide initial concepts and sizing for: o cross section of roads and ditches o foundation depth and types o pipeline alignments o return water systems. (collection and conveyance) o ore and waste delivery systems (slurry and solution pipelines, solution delivery, conveyance systems) o drainage and seepage collection **Description of other features, as applicable** • Leak detection systems • Liner systems • Water management plan for contaminated and clean water, including water storage, conveyance, treatment and discharge				
Information sources	• Descriptive waste and ore mineralogy and geochemistry	• Aerial topographic mapping	• Element-specific geotechnical and	• Targeted supplementary specific geotechnical		• Laboratory and field testing

TABLE C-1 – DESIGN LEVELS						
ATTRIBUTES	CONCEPTUAL	PRE-FEASIBILITY	FEASIBILITY	PRELIMINARY	DETAILED	AS-BUILTS
	• Description of terrestrial and aquatic environment • Description of socio-economic conditions • Description of surface and groundwater resources • Published topographic mapping • Typical tailings and heap leach ore physical characteristics • Site inspection observations • Compilation of available surficial and bedrock geologic mapping and geologic reconnaissance information • Estimated foundation conditions (surficial and bedrock geology, permafrost management) • A limited number of borings or other geotechnical field investigations may be required	• Site-wide geotechnical, hydrogeological, hydrological and water-quality field investigations (borings, test pitting, in-situ testing, sampling and laboratory analyses) • Borrow sources identification and mapping. • Preliminary seismic design criteria analysis • Laboratory geochemical testing or ore and waste (ARD and ML) • Field geochemical testing if necessary	hydrological field investigations • Borrow source field investigation • Project-specific tailings and heap leach ore physical characteristics	and hydrological field investigations • Element specific topographic surveys • Provincial and local applicable building codes • Available outcomes of assessment and permitting processes		conducted during construction • Element-specific topographic surveys
Climate data requirements	• Established climate baseline by using available observations for relevant climate variables • General permafrost and snowfield conditions	• Local climatic data collection from an on-site automated meteorological station • Permafrost and snowfield (glaciers) conditions		• Current and future climate extremes from World Meteorological Organization, based on temperature and precipitation to understand how		

Table C-1 – Design levels						
Attributes	**Conceptual**	**Pre-feasibility**	**Feasibility**	**Preliminary**	**Detailed**	**As-builts**
	• Long-term averages of current climate (e.g., climate normals) and observed trends over the baseline period • Long-term regional observation and climatic data • Projections for future climate based on the mean change (delta) from the climate baseline. The future climate projections chosen should indicate the data source, number of models used (e.g., GCMs), emission scenarios (e.g., RCPs), time period (e.g., 2050s, 2080s), and spatial resolution used (RCMs)			extremes are changing • Values of PMP and IDF that consider future climate • Design criteria – document climate events thresholds for adaptation pathways		

Appendix D
Options Assessment

February 2023

Yukon

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1. Objectives

1.1. Context

These guidelines are generally based on the methodology described in Guidelines for the Assessment of Alternatives for Mine Waste Disposal (Environment Canada, 2011). The Environment Canada guidelines were developed specifically for tailings management facilities; they have been adapted in this appendix to apply to different mine waste management facilities, closure plans and actions as described below.

1.2. Purpose

These guidelines describe the process that must be undertaken when a mining company is planning, designing, and closing the following facilities at a mine site:

- selection of a suitable tailings management facility (TMF) site as well as a tailings disposal methodology (see chapter 4.0 of the main document)
- selection of a suitable closure approach for a TMF (chapter 4.0)
- selection of a suitable heap leach facility type and location (HLF) (chapter 5.0)
- selection of a suitable closure approach for a HLF (chapter 5.0)
- selection of a suitable mine rock management facility (MRMF) site as well as a mine rock disposal methodology (see chapter 6.0)
- selection of a suitable closure approach for a MRMF (chapter 6.0)

1.3. Assessment of options

The options assessment described in this appendix are intended to be transparent and are required to be clearly documented in the environmental assessment documents. It is imperative to provide opportunities for representatives of First Nations, other government agencies and communities, as well as any independent review boards (IRBs) that may be involved to participate in the options evaluation and selection process. At a minimum, proponents should seek and consider input from these parties during the options analysis process as described in tables 4-2, 5-2 and 6-2 of the main document. This options assessment must objectively and rigorously assess all feasible options for the listed facilities and actions. When complete, the options assessment must describe the rationale for the selected option in both a narrative and quantitative sense.

The important aspects of an options assessment include:

- a transparent process;
- use of a well-known options analysis system. The approach described in this appendix if preferred, but alternatives will be considered if justified by the proponent;
- a clear set of standard definitions;
- evaluation criteria are not duplicated so as to overly weigh specific criteria; and
- a multi-disciplinary team should be used in compiling input as different disciplines have different perspectives in the criteria.

The analysis of options for mine waste management facilities (MWMF) relies on comparing the predicted characteristics of options against a series of criteria. The criteria established to support the options analysis must include not only the proponent's objectives related to waste management, but also the objectives of those with a long-term interest in the area. The identification and analysis of options for MWMFs must include the following:

- Seek and consider input from First Nations, assessors, regulators, government agencies and other interested parties throughout the identification and selection process, including engagement about the broad list of options, objectives, screening of options and comparative analysis of options.
- Include criteria to evaluate the relative performance of waste management options in relation to environmental, future land use, human health and safety, socio-economic conditions and requirements and risks. With respect to requirements and risk, include among a broad suite of criteria specific criteria for the following:
    - the consequence of failure;
    - the flexibility of the option to respond to early or unplanned closure; and

  - the annual cash flow cost (in current dollars) of long-term maintenance and surveillance for the closed facility.[1]

- To the extent practicable select potential sites that avoid:

  - destruction of salmon spawning habitat;
  - areas where others hold some form of tenure unless agreements are in place;
  - sites that contain heritage sites within the meaning of the Umbrella Final Agreement or final land claim agreement of affected First Nations[2]; and
  - affecting watersheds not already affected by the project.

- Screening analysis must, at a minimum, be based on pre-screening level designs for options while the comparative analysis should be based on conceptual level designs, as described in appendix C of the main document.
- Screening out of options based on cost can only be justified where the MWMF cost (capital, operating and closure cost) renders the project as a whole uneconomic.

2. Requirements for options assessment

The options assessment should assess all aspects of facilities and proposed actions that are necessary for the operation, closure and post-closure long-term monitoring and maintenance phases. The options assessment should also include all aspects of the project, direct or indirect, that may materially contribute to the predicted effects and impacts associated with each potential option. Examples of direct aspects of the project would be the need to consider options for the design of the mine and ore processing systems in the event they impact mine waste production, waste storage options, water management or water treatment. Indirect aspects include consideration of the

[1] Either on an average basis if relatively uniform or for discrete periods if distinct levels of cash flows will occur.

[2] Heritage sites can only be considered with the agreement of the governments that hold responsibility for ownership and management.

predicted quality and quantity of effluent that would be discharged from each option assessed, taking into account the applicable effluent quality limits and the predicted impacts (inclusive of mitigation measures, if any) on surface and groundwater water quality and flow.

An economic assessment of the options is also required and must consider the full costs of each option throughout the project's life cycle, i.e. from design through post-closure.

2.1. Options assessment process

The decision-making tools presented in this appendix allow technical specialists to communicate essential technical aspects while allowing interested parties to establish value judgments for the decisions being made.

Multiple accounts analysis (MAA) is the tool that has been selected to conduct assessments of options for mine waste management and other mining-related decision processes. This tool has been successfully used for a wide range of mine planning cases. In this analysis, numerical scores are created to represent the degree to which one decision option may be preferred over another. MAA seeks to integrate objective measurements with value judgment.

MAA consists of the development of a multiple accounts ledger, which is an explicit list of accounts and sub-accounts, for comparing the performance of the various options. Each account has an account indicator, which gives a clear understandable measurable description of performance. This is followed by a value-based decision process whereby indicator values are scored and weighted in a systematic transparent manner such that the value basis of the effects impacting of each is readily apparent.

MAA is part of a larger options assessment process. The overall process is illustrated graphically in figure 1. Each of the seven steps is described in greater detail in subsequent sections.

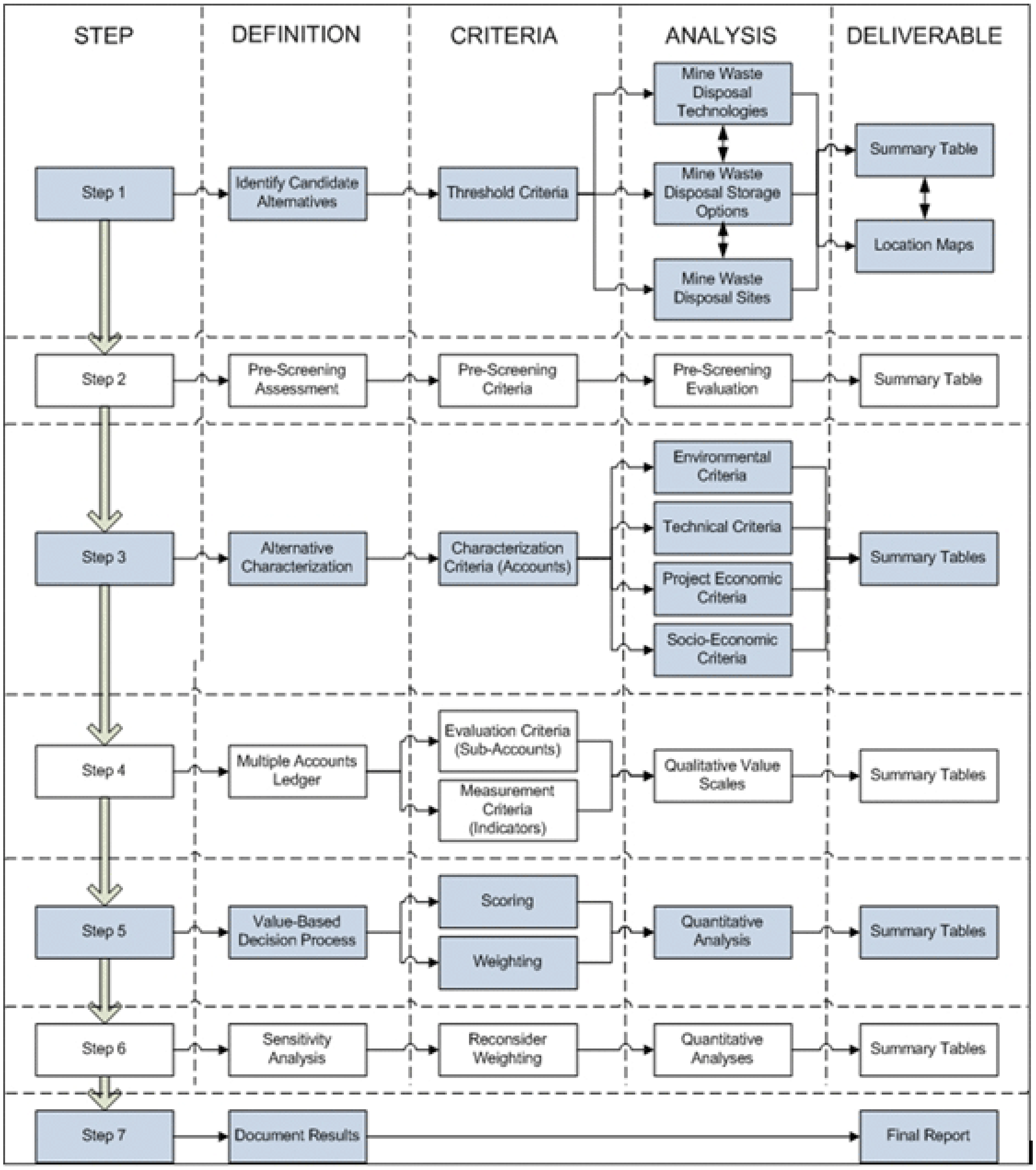

Figure D-1 Flow Diagram of the Process of Assessing[3]

2.2. Step 1: identify options

The first step in the options assessment process entails developing a list of possible, reasonable and realistic candidate options for the proposed facility, its

[3] Environment Canada, 2011

location or an action. The range of facility or action options that need to be considered can be found in the main document chapters listed in section 1.2 of this appendix.

It may be appropriate to establish a basic set of threshold criteria to establish the regional boundaries for selecting optional sites for a particular facility. These threshold criteria should be as broad as possible and must be fully described and rationalized to ensure transparency. Typical examples include:

- Exclusion based on distance: There is sufficient precedent to suggest that at some point the distance between the mill/mine complex and the facility becomes too great to ensure a positive economic outcome to the project. For any given project, this distance may be set.
- Exclusion based on presence of protected or environmentally sensitive areas: There may be protected areas within the regional boundaries considered for candidate mine waste disposal options. If it is known that a facility in these areas would not be allowed, these areas can justifiably be excluded from evaluation.
- Exclusion based on legal boundaries: Areas may be justifiably excluded from evaluation if legal boundaries would preclude mine waste disposal or some of the action being considered. These may include country borders or cadastral/land use/lease boundaries.
- Exclusion based on corporate policy: A mining company may have specific corporate sustainability policies that would eliminate a candidate option from consideration. These policies must be realistic, adopted by the company's board of directors, be described in the company's mission statements and procedures, and should not just be established for the specific project being evaluated. For example, these may include a policy statement limiting consideration of options that would require relocation of local inhabitants.

Economic criteria should not be used on their own as threshold criteria that lead to exclusion of certain methods or sites, for example exclusion of filtered tailings options, or options that require re-handling of waste, mainly because of higher costs.

2.3. Step 2: pre-screening assessment

Generally, it is not too difficult to develop a substantial list of options during step 1 of the process. However, this list of options should be pre-screened during step 2 to allow the decision process to be carried out on a smaller number of appropriate and manageable options. Pre-screening also entails excluding those options that are "non-compliant" in that they do not meet certain unique minimum specifications that have been developed for the project. This process is sometimes referred to as a "fatal-flaw analysis" in the context of mine waste disposal options assessments.

It is important to note that the objective of this step is not to "make less work" for the proponent, but rather to "optimize the decision making process" by not evaluating in detail options that have obvious deficiencies or that are obviously inferior in all aspects to others included in the smaller group .

Pre-screening criteria need to be uniquely developed for each options analysis, and a thorough qualification and justification of the rationale must be provided. It should be clear to external reviewers that the pre-screening criteria, when evaluated singly, are sufficiently important to eliminate an option from further consideration. The level of detail required to support that conclusion has to be evaluated on a case-by-case basis, and it may have to be extensive to be sufficiently supportive. It is generally recommended the amount of information and level of detail or each facility or action be consistent with the conceptual level of engineering described in appendix C (in the "purpose" row).

Pre-screening criteria should be formulated such that there is a simple "yes" or "no" response to whether the option does not comply with the set criteria. Most importantly, it must be clear to the external reviewer that there would be no reasonable mitigation strategy that would convert a "yes" (the option does not comply) into a "no" (the option does comply).

Examples of pre-screening criteria are presented below. These criteria should not be considered as practices that would be acceptable in all circumstances. It is incumbent on the proponent to select criteria according to these guidelines in order to determine which would provide the best practicable manner to achieve the project goals and provide for acceptable protection of human health, socio-economic values and the environment. The following questions should be considered:

- Would the site or action preclude future exploration or mining of a potential resource? A facility located over an area where there are proven indicators of mineralization, or a reasonable indication of possible mineralization based on regional trends, may be one possible reason to exclude it from further consideration. On the other hand, potentially attractive sites that have not been explored for mineralization should be included, as their ranking in the analysis would indicate whether these sites should be potentially explored for mineralization.
- Does part of the action proposed represent unproven technology? If a specific disposal method relies on technology that has not been demonstrated to be effective in the context of the site under consideration, then it could justifiably be argued that the option should be excluded from further consideration.
- Will the facility's capacity be too small to store the proposed upper limit of ore, mine waste or mine water? Unless there is good rationale to have more than one facility for any given project site, it can be argued that sites with insufficient capacity using reasonable containment approaches can be excluded from consideration.
- Will the facility result in an uneconomic project? It is justifiable to exclude a facility or action from further consideration if the company can clearly demonstrate that it would result in lowering the economic rate of return for the project to a level that would preclude the company from investing in the project. Where options are removed solely on the basis of economic reasons, well-documented analyses and rationales must be provided to support the decision.

Results of the pre-screening assessment are best presented in the form of a summary table that lists each option against the pre-screening criteria and associated rationale. Table 1 provides an example of what this summary table would look like. This table, complete with all applicable supporting information, will be the deliverable for this step, along with any supporting analyses.

Table D-1 Example of the Pre-Screening Criteria Summary Table

Table D-1 example of the Pre-screening Criteria Summary Table				
Pre-Screening Criteria	Rationale	Option A	Option B	Option C
Would the facility sterilize a potential resource?	A facility may be excluded from further consideration if it's located over an area where there are proven indicators of mineralization, or a reasonable indication of possible mineralization based on regional trends.	NO	YES	NO
Is any part of the facility or action unproven technology?	If a specific facility or action relies on unproven technology, then it can be argued that the option should be excluded from further consideration.	YES	NO	NO
Should option be excluded from further assessment?		YES	YES	NO

2.4. Step 3: option characterization

At this stage in the options selection process, there should be a reduced number of options remaining. There is no "ideal number" of options that should be carried through at this stage, but a general rule-of-thumb is that there would be three or more options remaining and determined to be worthy of detailed assessment.

These remaining options need to be further characterized for the following reasons:

- First, characterization of each option ensures that every aspect and nuance of the option is properly considered. The amount of information and level of design detail developed for each facility and action should generally conform to the "Refined Comparative Analysis of Options and Confirmation of Alternative Selection" described in appendix C.
- Second, the provision of thorough characterization in a clear and concise format that directly compares options ensures complete transparency of the options assessment process.

Site-specific *characterization criteria* should be developed for each options analysis. To facilitate smooth transition towards the next more rigorous steps of the evaluation process these criteria should be categorized into four broad categories, or “accounts,” that consider the entire project life cycle. This means that both short- and long-term environmental, technical and socio-economic aspects associated with construction through operation, mine closure and ultimately post-closure maintenance and monitoring need to be considered. The “accounts” can be summarized as follows:

- Environmental characterization: This account focuses on characterizing the potential effects on local and regional environment surrounding the proposed facility or action. These include but are not necessarily limited to elements such as climate and climate projections, geology, hydrology, hydrogeology, water quality, air quality and potential impacts on aquatic, terrestrial and bird life.
- Technical characterization: This focuses on characterization of the engineered elements of each option such as capacity, size and volume, diversion channel size and capacity, waste management techniques, haul distances, sedimentation and pollution control requirements, pipeline grades and routes, discharge and water treatment infrastructure and supporting infrastructure such as access roads. It also considers the design-for-closure approach, addressing performance for closure and post-closure phases of the project.
- Facility or action economic characterization: The focus of this account is to characterize the economics of the facility or action over its life cycle. All aspects of the facility or action need to be considered including investigation, design, construction (inclusive of borrow development and royalties where applicable), operation, closure, post closure care and maintenance, water management, associated infrastructure (including transport and deposition systems), compensation payments and land use or lease fees.
- Socio-economic and cultural characterization: This account focuses on how a proposed facility or action may influence local and regional land users. Elements that are considered here include characterization and valuation of land use, cultural and traditional use significance, presence of archaeological sites and employment and training opportunities.

Information must be developed and compiled to describe the performance of each option with respect to each characterization criterion. It is essential that the characterization remain factual, or where statements of judgment, risk, or uncertainty are made, that they be explicitly defined and qualified. In most cases there needs to be supporting information for these criteria in the form of technical reports completed by appropriately qualified specialists. It is also important to note that characterization of the options in this step does not entail evaluating impacts. Impact evaluation is included in Step 4 of the assessment process when a thorough characterization of each option is available.

Selecting and documenting characterization criteria should be done by a multidisciplinary team with representatives from all four accounts. In some cases, multiple representatives may be required from a single account, for example, a person familiar with the aquatic habitat in an area may not be familiar with the bird or terrestrial life. Clearly documenting the process that was followed throughout this step can greatly help to instill confidence of the external reviewer that all options have been thoroughly characterized. The development of criteria will also benefit from input from interested and affected parties. Seeking and considering input from local communities and First Nations will be particularly important when defining criteria for environmental and socio-economic performance.

Every project is unique, and as a result, it is not appropriate to provide a standardized list of characterization criteria against which to document options. The lists provided in table D-2 provide examples of characterization criteria that are likely to be required for the majority of projects. Naturally, the selection of criteria would also depend to some extent on the type of mine facility or action under consideration.

Table D-2 Example Characterization Criteria

TABLE D-2 EXAMPLE CHARACTERIZATION CRITERIA			
ENVIRONMENTAL	TECHNICAL	SOCIO-ECONOMIC AND CULTURAL	ECONOMIC
• Geographical boundaries (e.g. country/provincial/territorial/municipal boundaries, land claim/land use/traditional use/cadastral/other re-defined boundaries) • Topography (e.g. relief, complexity of topography) • Geotechnical and seismic conditions (e.g. geological setting, depth of overburden or permafrost, fault/fracture zones) • Hydrology (e.g. surface water features, size of streams/rivers/lakes/wetlands, catchment boundaries, flood lines) • Hydrogeology (e.g. depth to groundwater, perched water tables, presence of springs/artesian wells) • Climate (e.g. temperature, precipitation, evaporation, prevalent wind strength and direction, snow drifting, precipitation and temperature inversions) • Climate change projections (e.g. predicted changes in precipitation patterns and extreme precipitation events, warming impacts in permafrost areas) • Atmospheric issues (e.g. particulates, heavy metals) • Overall affected land footprint size of impoundment (including ancillary facilities such as secondary/polishing ponds), related infrastructure (e.g. dams, saddle dykes) and access roads • Water quality (e.g. surface water, groundwater, naturally or previously impacted waters) • Special features (e.g. seismicity, avalanches, permafrost, radioactivity) • Vegetation (e.g. types, rarity/uniqueness, coverage)	• Physical characterization of wastes (e.g. grain size distribution, settlement rate, strength and consolidation parameters) • Geochemical characterization of wastes (e.g. acid rock drainage and metal leaching, reagents, explosive residues, physical and chemical degradation etc. • Geochemical characterization of all construction materials and associated excavation waste (e.g. unsuitable soils stripped from foundations, quarries, or other borrow sources) • Facility design (e.g. overall affected land footprint size of impoundment (including secondary/polishing ponds), related infrastructure (e.g. dams, saddle dykes), access and haul roads • Containment structure design (e.g. size, hydraulic capacity, artificial materials, substrate, possible use of impermeable or geo-textile liner for impoundment) • Diversion structure designs (e.g. size, hydraulic capacity, construction materials, substrate) • Supporting infrastructure design (e.g. type, size, construction materials, substrate) • Borrow source and quarry design (e.g. size, volumes extracted, development methods, water management, rehabilitation) • Tailings delivery and deposition system design (e.g. type, capacity, location, containment) • Water management system design (e.g. water balance, discharge strategy, water treatment strategy, recycle strategy) • Closure design (e.g. approach, construction materials)	• Archaeology (e.g. location, size, type, importance, risk of unidentified sites such as burial sites) • Community/Aboriginal land/mineral use rights (e.g. formal/informal agreements, grandfathered agreements) • Maintenance of traditional lifestyle (e.g. loss of hunting, fishing or natural food harvesting, loss of access) • Ecological/cultural values (e.g. value of land, value of water, value of aquatic, bird or terrestrial species, value of lifestyle) • Perception (e.g. apparent acceptance or distrust, nature of communication) • Previous and existing land use (e.g. recreation/tourism, spiritual well-being, mining, industry, hunting, fishing) • Expected future land use • Aesthetics (e.g. line of sight, landform engineering, re-vegetation) • Employment (e.g. short- and long-term opportunities, "boom-and-bust" cycles, plans for sustainable economic development) • Capacity building (e.g. training opportunities, contracting opportunities, community infrastructure). This is often also includes building government capacity. • Economic benefits (e.g. partnerships, royalties, lease payments, compensation and benefit agreements)	• Capital cost (e.g. investigations, design, borrow development, construction, supervision, commissioning, etc.) • Operational cost (e.g. labor, reagents, equipment, power, supervision, monitoring, maintenance, water treatment, etc.) • Closure cost (e.g. bonding, investigations, design, borrow development, construction, supervision, commissioning, monitoring, water treatment) • Post-closure cost (e.g. monitoring, maintenance, inspections, water treatment) • Fish habitat compensation (e.g. bonding, construction, monitoring) • Land use cost (e.g. land use fees, lease rates, royalties on borrow materials) • Economic risks and benefits (e.g. permitting timelines, construction seasonality, design and cost estimate certainty, post-closure timeline

Table D-2 Example Characterization Criteria			
Environmental	**Technical**	**Socio-economic and Cultural**	**Economic**
• Aquatic life and habitat (e.g. species variation/uniqueness, habitat suitability) • Terrestrial life and habitat (e.g. species variation/uniqueness, habitat suitability) • Bird and wildlife and habitat (e.g. species variation/uniqueness, habitat suitability	• Flexibility (e.g. ability to handle upset conditions – chemical/volumetric/physical – as well as expansion capacity, variable discharge strategies) • Precedent (e.g. new technologies, case studies – should include thickened, paste or dry stacking options) • Design and construction of impermeable covers over wastes • Technical risks and benefits (e.g. variable foundation conditions, water balance) • Constructability (e.g. seasonality, access)	• Community safety (e.g. construction methods, operational management of facility, closure state of facility) • Overall perceived socio-economic consequences, benefits and relative preferences	

The deliverable for this step should ideally be a series of summary tables that list the selected characterization criteria for each account for each of the options or actions under consideration. The tables should include a concise summary of the rationale behind each criterion. This format allows an external reviewer to easily compare the factual characteristics across options. The tables will likely be supported by technical appendices that provide details about analysis conducted to define performance of various options with respect to specific criteria.

Tailings treatment methods – for example, conventional slurry tailings, thickened or high-density tailings, paste and filtered tailings – are an important consideration when doing the alternatives analyses. Each has a very different impact in terms of operations (conventional being the easiest to produce within expectations and filtered the hardest). Each also has very different economic, environmental and risk factors.

Typically, the alternatives selected should include combinations of different sites, each combined with one of more tailings treatment methods. Table D-3 below provides an example of what a summary table may look like for three different sites that are considered for either conventional or thickened slurry deposition. The same three sites could also be considered for alternate treatment methods, for example filtered tailings. The summary table for these combinations would include the key characteristics of the filtered tailings stacks, rather than the dams indicated in table D-3. An example table for the filtered options is not provided in this appendix.

Table D-3 Example of the Characterization Summary Table for Conventional and Thickened Tailings

Table D-3 Example of the Characterization Criteria Table for Conventional and Thickened Tailings				
Account: Technical Characterization for a Tailings Management Facility				
Characterization Criteria	**Rationale**	**Option A**	**Option B**	**Option C**
Dam size	Larger dams are more complex, pose greater risk, require more construction materials, require a larger footprint, create greater post-closure liability	One dam, 300 m long, 20 m total height, final dam footprint of 2 ha	Two dams; first is 150 m long, 30 m high with a footprint of 1 ha; second is 200 m long, 15 m high with a footprint of 2 ha	Two dams; first is 400 m long, 30 m high with a footprint of 3 ha; second is 50 m long, 20 m high with a footprint of 0.5 ha
Dam foundation conditions	Dams constructed on poor foundation conditions are more complex, pose greater seepage and stability risk, longer construction periods, more complex monitoring requirements	Shallow (3 m thick) glaciofluvial soil overlying competent intact bedrock	Shallow (0.5 m thick) organic layer overlying 5-8 m thick bouldery till, overlying fractured bedrock with competent bedrock at great or unknown depth	Shallow (3 m thick) glaciofluvial soil overlying competent intact bedrock or bedrock with only minor jointing and fracturing which can be reliably treated.
Supporting infrastructure	More supporting infrastructure results in greater demand on construction material, occupy larger footprint, greater risk of systems failure, more complex closure	2 km perimeter diversion ditches on steep side slopes; 20 m wide spillway can be provided over an existing rock abutment; 5 km access road; and 4 km service road for discharge spigots	5 km of perimeter diversion ditches on relative flat topography; two 15 m wide spillways that need to be concrete lined; 3 km access road and 8 km ring road to service discharge spigots	Terrain too steep for perimeter diversion ditches; a 10 m wide spillway through a rock cut and a 20 m spillway that requires concrete lining; 10 km access road and 7 km service road for discharge spigots

2.5. Step 4: multiple accounts ledger

Up to this point in the process, the emphasis has been on identifying and characterizing options. In order to evaluate options using the MAA decision-making tool, it is necessary to develop a multiple accounts ledger. This ledger seeks to identify those elements that differentiate options and actions, and provides the basis for scoring and weighting as described in step 5, which is necessary to complete the evaluation. The multiple accounts ledger consists of the following two elements:

- Sub-accounts, known as evaluation criteria, and;
- Indicators, known as measurement criteria.

Complete definitions and procedures for developing sub-accounts and indicators are described in the following sections.

2.5.1. Sub-accounts

Sub-accounts (evaluation criteria) are developed using the characterization criteria selected during Step 3. The fundamental difference between these sets of criteria is that characterization criteria are factual and have been developed without prior judgments being made regarding any of the options being considered, while evaluation criteria consider only the material impact (i.e., benefit or loss) associated with any of the options being evaluated.

The choice of sub-accounts must be carefully considered so that only those sub-accounts that truly differentiate options are presented for evaluation. To facilitate this, sub-accounts should comply with the following guidelines:

- Impact driven: The evaluation criteria must, as far as practicable, be linked to an impact as opposed to merely being a factual element. For example, the size of an impacted lake in itself is not a relevant sub-account, but if the size of the lake is linked to its value or potential habitat water-supply loss, then the sub-account is appropriate.
- Differentiating: The sub-account must define an aspect that distinctly differentiates one option or action from another, and that difference is expected to have a material effect on the final selection of an option or action. For

example, land ownership may be an important evaluation criterion, if different options fall on ground with different ownership. Conversely, if all the mine waste disposal options under consideration were on land belonging to a single owner, then there really is no need to consider this sub-account in the analysis.

- Value relevance: A sub-account must be relevant in the context of the options being evaluated. For example, the size of dams in itself is not a relevant sub-account unless it is linked to a relevant context such as increased long-term risk of failure or increased maintenance and inspection requirements.
- Understandability: Sub-accounts must be unambiguously defined and described, such that two external reviewers cannot interpret the outcome differently. For example, distance between the facility and the mill complex may be a sub-account with the understanding that greater distances pose greater technical and environmental risk (and the distance should be measured in the manner related to these impacts, such as either road or straight-line distances). However, someone may assume that because there is a significant dust hazard associated with a proposed option or action, a greater distance could be advantageous due to reduced worker health and safety risks.
- Non-redundancy: There should not be more than one sub-account that measures the same evaluation criteria. If individual sub-accounts measure similar criteria, consideration should be given to combining those criteria.
- Judgmental independence: Sub-accounts should be judgmentally independent, which means that preferences with respect to a single criteria, or trade-offs between criteria, cannot depend on the value of another. For example, assume "traditional land use" is one sub-account and another is "landowner perception." It may be concluded that for one option "hunting" will be impacted, which would result in a negative impact on "traditional land use." However, if "landowner perception" is influenced by a decrease in hunting then judgmental independence does not exist. In this case, it may be better to select either, but not both, of these as sub-accounts (or to select one sub-account, which includes both).

As with all the other criteria mentioned throughout this options assessment process, there is no "master list" of evaluation criteria applicable to all projects and there is no ideal number of evaluation criteria. These should be defined on a project-specific basis by a multi-disciplinary team with input from interested parties, as necessary and as described in the main document.

The deliverable at this stage in the process will be a summary table that lists the sub-accounts complete with the rationale behind each. Appropriate supporting documentation should be referenced. Table D-4 provides an example of what this summary table may consist of.

Table D-4 Example of the Sub-account (Evaluation Criteria)

Table D-4 Example of the Sub-Account (Evaluation Criteria)		
Summary Table for a Tailings Management Facility		
Account	**Sub-account**	**Rationale**
Environmental	Distance from mill site (straight line or road, as applicable)	A longer distance implies that the risk of an accidental spill of tailings along the pipeline is greater. Greater distance further implies more linear infrastructure that negatively affects caribou migration. Less accessibility by operational staff may lead to less intensive management of the TMF operations.
	Value of aquatic life affected	A lake with larger species diversity and health has been deemed to carry greater value from a traditional use perspective.
	Post-closure land use	Options that would most closely return land use to pre-mining conditions or to a state that provides some benefit to the landowner would be more palatable to the landowner.
Technical	Containment structure design	Larger or more complex containment structures are generally less desirable due to uncertainty associated with long-term integrity particularly if the area is seismically active. Depending on the nature of the containment, this can also increase the risk of cost overruns and closure not achieving the objectives.
	Water management system	Long-term active water treatment is not desirable due to long-term risks associated with treatment sludge handling and storage.
	Complete system flexibility	Waste characteristics are expected to change over the life of the project, affecting physical stability and water management strategies. Options that are least susceptible to risks associated with these changes are preferred.
	System resilience	Resilient systems are less likely to fail, create reduced consequence when failures do occur, and both the facility and the impacted environment tend to return to acceptable conditions more quickly than non-resilient systems.
Project economics	Capital (and sustaining capital) cost	Generally, the lower the costs, the higher the particular option is rated against other options with higher costs.
	Operational cost	Generally, the lower the costs, the higher the particular option is rated against other options with higher costs. By applying different relative weights for capital and operating costs, the decision can be weighted towards one or the other criterion.
	Closure and post closure cost	Generally, the lower the costs, the higher the particular option is rated against other options with higher costs.
Socio-economics and cultural	Archaeology	The prevalence of archaeological sites in the region implies complete avoidance will be impossible. Sites that would minimize the impact would be more amenable.
	Society and culture	A regulatory proposal may have impacts or implications on people's way of life, culture, community, and well-being. Consideration should be given to vulnerable social and economic groups such as Aboriginal peoples.

Table D-4 Example of the Sub-Account (Evaluation Criteria)		
Summary Table for a Tailings Management Facility		
Account	Sub-account	Rationale
	Traditional land use value	It would be less desirable to impact areas that have direct use values (e.g. agriculture, recreation, tourism, and functional ecosystem benefits) as well as passive values such as the existence value of the natural habitat and ecosystem.
	Socio-economics	Some projects or site developments may create more opportunity for jobs and skilled-labor training. This parameter can be omitted in the event the options have a similar impact on the regional economics.
	Perception	Tailings, irrespective of their geochemical composition, are generally perceived to be highly toxic by the local communities. Therefore, where this is true, TMFs where animals and birds could have direct contact with tailings are less desirable.

2.5.2. Indicators

To allow qualitative or quantitative measurement of the impact (i.e., benefit or loss) associated with each option for any given sub-account, the sub-account needs to be measurable. Sub-accounts by nature are often not directly measurable, and need to be sufficiently decomposed to allow measurability. This decomposition takes the form of sub-sub-accounts, which in the language of MAA are called indicators, or measurement criteria.

The concept of indicators is best described by examples:

- *Example 1*: The sub-account "traditional land use" may have a list of indicators (sub-sub accounts) including "effects on hunting," "effects on fishing" and "effects on harvesting berries."
- *Example 2*: The sub-account "water quality" may have a list of indicators (sub-sub accounts) including "pH," "conductivity," "TDS," etc.

These indicators may be different for the different life-cycle stages of the project (i.e., construction, operation and closure) and, where appropriate, may be divided into separate periods.

When selecting indicators thought should be given to the parameter that will be used to define measurability. This measurability is required in order to continue to Step 5, which is the value-based decision process. Assigning measurability is relatively simple for sub-accounts that readily lend themselves to parametric terms such as "water quality" or "capital costs." The challenge comes when measurability needs to be assigned to sub-accounts that do not readily lend themselves to parametric terms such as "traditional land use," which must be supplemented by sub-sub accounts, such as "effects on hunting."

This problem can be overcome by constructing qualitative value scales. An example of such a scale is provided in table D-5 below.

Table D-5 Example of a Qualitative Value Scale

TABLE D-5 EXAMPLE OF A QUALITATIVE VALUE SCORE		
CONSTRUCTABILITY OF A TAILINGS MANAGEMENT FACILITY		
SCORE	QUALITATIVE SCORE	DESCRIPTOR
4 (Best)	**Straightforward**	Readily constructible using local construction crews with limited oversight, and construction methods and schedule is resilient to inclement weather conditions. The site is not remote or has easy, all-weather access, or if seasonal access only, then construction will also only be seasonal.
3	**Moderately complex**	Construction requires experience only regional contractors possess. A modest amount of oversight is required. The sight is more remote and has seasonal access limitations that can be managed relative to the construction schedule.
2	**Complex**	Construction requires experience only regional contractors possess. A significant amount of oversight and quality control and assurance is required. Specialty works such as permafrost mitigation is a significant component of the project. Seasonal access is an important consideration.
1 (Worst)	**Very complex**	Construction requires contractors with international experience in similar structures and significant amount of oversight, quality control and assurance. Seasonal access and winter construction are important or critical considerations.

In order to develop a qualitative value scale it is necessary to define at least two points on the scale (usually the end points). The points on the scale are defined descriptively and draw on multiple concepts in the definition of the indicator. The number of points on the scale will be determined by the indicator definition, and a good rule of thumb would be to target a four- or six-point scale. This provides for sufficient capacity to differentiate, without being overly onerous. Also by providing an even number scale, the tendency to select the "middle-of-the road" value is eliminated. Qualitative value scales should be developed to have the following characteristics:

- Operational: The decision maker should be able to rate options that were not specifically used to define the scale, e.g., should another facility be added for evaluation at a later time, the scale developed previously should still be relevant.
- Reliable: Different external reviewers should be able to rate an option according to the value scale and assign the same score.
- Value relevant: The value scale must be directly relevant to the indicator being scored.
- Justifiable: Any external reviewer should reach the conclusion that the value scale is reasonable and representative.

The deliverable for this part of the process will be the expansion of the sub-accounts summary table to include indicators. As previously stated, this collective information is also known as the multiple accounts ledger, and Table D-6 provides an example of what this may look like. Within table D-6, the indicators "fishing impact" and "ARD potential" are examples where indicator parameters are based on a qualitative value scale. This qualitative value scale must be documented, and table D-7 provides an example of what this may look like.

Proponents should seek and consider input from government agencies, First Nations and communities when defining indicators and establishing qualitative value scales as described in the main document.

Table D-6 Examples of Multiple Accounts Ledger Accounts

TABLE D-6 EXAMPLE OF MULTIPLE ACCOUNTS LEDGER ACCOUNTS					
ACCOUNT	SUB-ACCOUNT	INDICATOR	INDICATOR PARAMETER	UNIT	INDICATOR QUANTITY
Environmental	Effect on traditional land use during construction	Hunting impact	Time	Yr.	2 years
		Fishing impact	Value	# (See Table D-7)	3
		Berry harvesting impact	Area	ha	400 ha
Mine waste geochemistry	Mine waste Geochemistry	ARD potential	Value	#	2
		Metal leaching potential	Value	#	6
	Diversion design	Channel length	Length	km	3.8 km
		Catchment size	Area	ha	134 ha
Project economics	Life of mine cost	Capital cost	Cost	$	10 million
		Operational cost	Cost	$	2 million/yr.
		Closure cost	Cost	$	3 million
	Economic risk	Capital	Value	#	2
		Operational	Value	#	3
		Closure	Value	#	5
Socio-economic	Landowner perception	Land owner perception	Value	#	4
	Archaeological sites	Presence of immovable sites	Quantity	#	2
		Presence of mitigatable sites	Quantity	#	33

Table D-7 Example of Qualitative Value Scale for the Indicator "Fishing Impact" Listed in Table D-6

TABLE D-7 EXAMPLE OF QUALITATIVE VALUE SCALE FOR THE INDICATOR "FISHING IMPACT" LISTED IN TABLE D-6	
SCORE	**DESCRIPTOR**
6 (Best)	No impact
5	Short-term temporary loss of some fishing (some species or some areas, but not all). During construction, fishing in the area will be prohibited for health and safety reasons.
4	Loss of fishing for foraging species for at least 10 years.
3	Loss of fishing for foraging species and 1 large-body species for at least 10 years.
2	Loss of fishing for foraging species and 2 large-body species for at least 10 years.
1 (Worst)	Complete and permanent loss of all fishing for the life of the project and into perpetuity.

2.6. Step 5: Value-based decision process

At the conclusion of Step 4, the multiple accounts evaluation is complete and the value-based decision process begins. This process entails taking the list of accounts, sub-accounts and indicators and assessing the combined impacts for each of the options under review. This entails scoring and weighting of all indicators, sub-accounts, accounts, and quantitatively determining merit ratings for each option. These three processes are described in the following sections.

2.6.1. Scoring

Scoring is done by developing qualitative value scales for every indicator, including those that appear to be readily measurable. An example of such a qualitative value scale is presented in table D-8. The process of how these are developed has been described in Step 4. By following this procedure, it should become obvious why a particular indicator score has been assigned to an option, and if the qualitative value scale has been developed collaboratively, with input from or review by interested parties, there is built in confidence that the scoring is appropriate.

Table D-8 Example of Qualitative Value Scale (for an indicator such as "capital cost")

Table D-8 Example of Qualitative Value Scale (For an Indicator such as “Capital Cost”)	
Score	**Descriptor**
6 (Best)	Less than $10M
5	Between $10 and $20M
4	Between $20 and $30M
3	Between $30 and $40M
2	Between $40 and $50M
1 (Worst)	Greater than $50M

It is important to establish the worst cost value based on the scale of the option considered so that a realistic comparison of options can be undertaken. The best case value should generally be under a relatively small cost ($) value, while the worst ranking should slightly exceed the highest cost option being considered. For example for a tailings options that cost between $80 and $120 million, the best to worst scales could be < $25 million, 25 to 50, 50 to 75, 75 to 100, 100 to 125, and 125 to $150 million. This means the options would all score between 2 and 3, reflecting the relatively small differences in total costs.

2.6.2. Weighting

At this time the analyst, with input from interested parties, needs to have the ability to introduce their value bias between individual indicators. This is done by applying a weighting factor to each indicator, which must be present along with rationales. Weighting factors allow the analyst to assign relative importance of one indicator as compared to another, and this weighting factor is most likely to reflect the analyst’s bias or value basis.

It is important to bracket the weighting factor, and in the context of these guidelines, it is recommended that the weighting factors range from 1 through 6. This means that any one indicator can be considered to be up to 6 times more significant than another. If the multiple accounts evaluation has been rigorously carried out, then this range of weighting factors should be sufficient to satisfy an external reviewer. Further consideration of weighting factors can be conducted during the sensitivity analysis (section 2.7 – Step 6). Weighting factors should be constant for any given indicator, sub-account or account across all options or actions.

Generally, the analyst with input from interested parties should set weighting factors that reflect the site-specific conditions and sensitivities. In addition to these weights, within the framework of these guidelines, it is proposed that a “base case” of the options assessment be initially performed using the following weightings for accounts:

- Environment – 6
- Technical – 3
- Project economics – 1.5
- Socio-economic – 3

The analyst is still encouraged to assign other weightings to accounts and demonstrate their effect on the assessment outcome, as described in section 2.7 – Step 6.

Recognizing that for an external reviewer it may not be immediately apparent how the chosen weighting factors effects the outcome of the options assessment, it is recommended that in all cases the analyst produce several sensitivity analyses (Step 6).

2.6.3. Quantitative analysis

The quantitative analysis is relatively simple, and given the potentially large amount of accounts, sub-accounts and indicators, this analysis is well suited to using a spreadsheet-type approach or commercially available software that perform the same calculations but which can provide for easy to perform sensitivity analyses and graphical output. For each indicator, the **indicator value (S)** of each option is listed in one column. The **weighting factor (W)** is listed in another column and the combined **indicator merit score (S × W)** is calculated as the product of these values. An example of this analysis is presented in Table D-9.

Indicator merit scores can be directly compared across options, and likewise **sub-**

account merit scores (Σ{S × W}) can be directly compared across options. However, to allow comparison of these values against values for other sub-accounts, the scores must be normalized to the same six-point scale used to score each indicator value. This is achieved by dividing the sub-account merit score by the **sum of the weightings (ΣW)** to yield a **sub-account merit rating (R_s = (Σ{S×W}/ ΣW)**. This will again be a value between 1 and 6. This normalization is necessary to balance out different numbers of indicators and sub-accounts for each account. Without this normalization, the number of indicators associated with each sub-account, and the number of sub-accounts associated with each account, would have to be identical, otherwise the analysis will be skewed by accounts with more sub-accounts or indicators.

Table D-9 Example of the Quantitative Analysis for Indicators

Table D-9 Example of the Quantitative Analysis for Indicators					
Account: Socio-economic Sub-Account: Effect on traditional land use during construction					
Indicator	Indicator Weight (W)	Option A		Option B	
		Indicator Value (S)	Indicator Merit Score (S × W)	Indicator Value (S)	Indicator Merit Score (S × W)
Hunting impact	2	6	12	1	2
Fishing impact	5	3	15	4	20
Berry harvesting impact	1	5	5	2	2
Sub-account merit score (∑{S × W})			32		24
Sub-account merit rating (R_s = ∑{S×W}/ ∑W)			4		3

The same procedure of weighting and normalization is followed to determine **account merit scores (∑{R_s×W})** and **account merit ratings (R_a = ∑(R_s×W)/ ∑W)**. This is illustrated in Table 13. This process is repeated one final time, and an **option merit**

score ($\sum\{R_a \times W\}$) and an **option merit rating ($A = \sum(R_a \times W) / \sum W$)** is determined for each of the options, as illustrated in Table D-10.

Table D-10 Example of the Quantitative Analysis for Sub-accounts

TABLE D-10 EXAMPLE OF THE QUANTITATIVE ANALYSIS FOR SUB-ACCOUNTS					
ACCOUNT: SOCIO-ECONOMIC					
SUB-ACCOUNT	INDICATOR WEIGHT (W)	OPTION A		OPTION B	
		SUB-ACCOUNT MERIT RATING (R_S)	SUB-ACCOUNT MERIT SCORE ($R_S \times W$)	SUB-ACCOUNT MERIT RATING (R_S)	SUB-ACCOUNT MERIT SCORE ($R_S \times W$)
Effect on traditional land use during construction	6	4 (From Table D-9)	24	3 (From Table D-9)	18
Archaeology	1	6	6	6	6
Aesthetics	3	5	15	3	9
Account merit score ($\sum\{R_s \times W\}$)			45		33
Account merit rating ($R_a = \sum\{R_s \times W\} / \sum W$)			4.5		3.3

Table D-11 Example of the Quantitative Analysis for Accounts

TABLE D-11 EXAMPLE OF THE QUANTITATIVE ANALYSIS FOR ACCOUNTS					
ACCOUNT	INDICATOR WEIGHT (W)	OPTION A		OPTION B	
		ACCOUNT MERIT RATING (R_A)	ACCOUNT MERIT SCORE ($R_A \times W$)	ACCOUNT MERIT RATING (R_A)	ACCOUNT MERIT SCORE ($R_A \times W$)
Socio-economic	3	4.5	13.5	3.3	9.9
Technical	3	5.1	15.3	4.5	13.5
Project economics	1.5	3.4	5.1	5.6	8.4
Environment	6	4.4	26.4	3.8	22.8

Option merit score ($\sum\{R_a \times W\}$)	60.3		54.6
Option merit rating ($A = \sum\{R_a \times W\} / \sum W$)	4.5		4.0

At this time, it is possible to compare option merit ratings for all options evaluated, and the preferred option will be the one that has the highest merit rating.

The deliverable at this point in the process will be summary tables much like the examples presented in this section. It is, however, very important that justification is provided for all the weightings used along every step of the process. An external reviewer should be able to review the weightings and conclude that they are reasonable, even though they may not agree with them.

2.7. Step 6: Sensitivity analyses

The options assessment and subsequent value-based decision-making process described in these guidelines is specifically tailored to be transparent, and to the extent practicable eliminate bias and subjectivity. However, the reality is that any decision-making process is subject to bias and subjectivity, and the goal is to be transparent about that bias and subjectivity to the point where an external reviewer can understand the value system that led to the selected option.

The way to test the sensitivity of the value-based decision-making process is to assign different weightings to those indicators, sub-accounts and accounts according to a range of value systems representative of the perceived disparity.

With one exception, the level and type of sensitivity analysis that should be carried out is not set, and should not be prescriptive. It is entirely project specific and to a large extent will be based on feedback received from interested parties throughout the options assessment process. It is recommended that at least one sensitivity case be analyzed, and that is one where all the main account indicator weights are assigned an equal value (i.e. a weighting of 1). Other cases can be analyzed using weights established by the proponent for the site-specific conditions, and can also include weights defined by First Nations and other key interested parties.

Table D-12 presents an example of sensitivity analysis runs completed on the example dataset presented in table D-9 to D-11. The merit rating of each option is compared to the base case analysis to determine if the results of the sensitivity analysis are likely to lead to a different decision about which option may be the preferred option. In this example, all but the project economics focus case would have resulted in a different option rating the highest. The table also informs on which account is the largest contributor to the merit rating. This information can be helpful in determining where further discussion or data are needed to refine the analyses.

It is conceivable that specific interested parties may have completely biased opinions about how weightings should be evaluated, which may unfairly skew the assessment results. Sensitivity analysis is not intended to resolve this disparity. It does, however, provide a platform for presenting these opinions in a transparent manner where any interested party or external reviewer can make their own value judgments about all interpretations of the case.

Table D-12 Example of the Results of a Sensitivity Analysis

TABLE D-12 EXAMPLE OF THE RESULTS OF A SENSITIVITY ANALYSIS				
ANALYSIS ID	SCENARIO DESCRIPTION	MERIT RATING		HIGHEST RANKING ACCOUNT
		OPTION A	OPTION B	
Base case	As per tables D-9 and D-10	4.4	4.1	E
Base case sensitivity	Using equal weights in table D-10	4.4	4.3	T
#1 Socio-economic focus	Change table D-10 weights form 3/3/1.5/6 to 6/3/3/3	4.4	4.1	SE
#2 Technical focus	Change table D-10 weights to 3/6/3/3	4.5	4.3	T
#3 Project economic focus	Change table D-10 weights to 3/3/6/3	4.2	4.6	PE
#4 Environmental focus	Change table D-10 weights to 3/3/3/6	4.4	4.2	E
#5 Hunting focus	Change table D-8 weights to 5/2/1	4.6	3.9	E

#6 Aesthetics Focus	Change table D-9 weights to 3/1/6	4.6	4.0	E

MAA as described in these guidelines uses weighting factors to encourage interested parties to scale the importance of indicators according to their own value system. If the assignment of weighting has been done collaboratively with the appropriate interested parties, then it is probably reasonable to assume that those weightings suggest general consensus. However, it is to be expected that some indicators could expose diametrically opposing value systems, and as a result, general agreement on individual weightings may not be reached. At this point, it is recommended the analysis be performed with both weighting systems in order to identify whether the selected option or action would differ, and if it does, identify which accounts or sub-accounts are the cause of the difference. This will allow further discussions to be focused on these accounts to see if resolution can be reached. In some instances, it might lead to more work being done to better understand these accounts and to develop more reliable merit ratings.

The deliverable for this step would be a well-documented summary of the sensitivity analysis that was carried out. This may be presented in summary tables similar to those presented in Step 5 and Table D-12.

2.8. Step 7: document results

The final step in the options assessment process entails thorough documentation of the results. This is best done through a comprehensive technical report, which systematically describes the outcome of each of the steps as recommended in these guidelines. The primary technical options assessment report should be a concise summary of the findings of each step, using comparative summary tables and descriptive definitions that make the results immediately apparent to the external reviewer. Detailed supporting information related to elements such as cost-estimate breakdowns and geochemical assessments should be presented in appendices, or if stand-alone reports have been produced, these should be properly referenced and made available for review.

References

Environmental Canada, 2011. *Guidelines for the assessment of alternatives for mine waste disposal*. Government of Canada.

Appendix E
Risk Assessment Approach

February 2023

Yukon

Executive summary

This appendix describes the procedures for risk management including performing the risk assessments described in the various sections of the main document. These procedures are based largely on Risk Management – Principals and Guidelines (ISO 31000:2018) and Risk Management – Risk Assessment Techniques (IEC 31010:2019), and have been adapted for the mining industry and conditions in the Yukon.

Risk assessments are required not only to establish what the risks are, but also to put in place suitable risk treatment or management processes. For risk treatment processes to be effective, they should become an integral part of the mining company's management and be embedded in the culture and practices of the mining company.

The risk management processes (Section 3.0 below) and techniques (Section 4.0 below) outlined in this appendix provide guidelines for how risks associated with all phases of a mining project (planning, development, operations and closure) can be identified and managed by the mining company. Further guidance on the corporate side of risk management can be found in ISO 31000:2018.

These guidelines recognize that each mine site is unique and that modifications or refinements to the approach described here may be necessary. In the event these are proposed, the rationale for any changes should be provided for review by the Yukon government.

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Glossary

Climate variable	A weather parameter that can be measured and projected into the future (e.g. temperature, precipitation) and that has the ability to interact with mine infrastructure and operations.
Consequence	The health and safety, social, environmental, cultural and economic impact caused by the effects of a failure occurring.
Contingency measures	Measures that can be implemented in the event monitoring of a facility indicates that the probability or the consequence of a failure mode is higher than previously characterized.
Effect	A description of what happens when the failure occurs.
Emergency response plans	Plans that are put in place and that are activated when a failure occurs and that are used to prevent or limit the consequences of the failure.
Failure mode	A method by which a mine facility or a component of that facility can either physically fail or not perform as intended by the design and operational procedures.
Hazard	A potential source of harm or adverse effect.
Likelihood	The probability that the failure mode will occur and should be expressed as a probability of occurrence during the time period for which the risk assessment is being performed; e.g. a specific operating period, a 100-year or longer post-closure period. It is important to recognize that failures with low annual probabilities have a much higher probability of occurrence during a very long period, such as the closure period of a mine. This is illustrated by Table E-1 below.

Table E-1 Probabilities of design flood events being exceeded

Facility Component Design Flood Event	Probability Design Event is Exceeded in the Following Period (Years)				
	1	25	50	100	200
1-in-50 year	2%	40%	63%	87%	98%
1-in-100 year	1%	22%	40%	63%	87%
1-in-1,000 year	0.1%	2.5%	5%	10%	18%
Probable maximum flood, assuming 1-in-100,000 years	0.00%	0.02%	0.05%	0.10%	0.20%

Risk	The likelihood that some form of harm or adverse effect can occur.
Risk rating	The ultimate result of the risk analysis. It combines the likelihood and consequence of each failure mode to assess the overall threat level. Generally, high threat levels range from likely failure modes with moderate consequences to low likelihood events with significant consequences.
Risk treatment	Typically includes changes to facility design elements or operational procedures intended to minimize the likelihood and the consequence of a failure. They also include contingencies and emergency response plans.
Vulnerability	A vulnerability occurs when a climate variable interacts with mine infrastructure in a manner that has the potential to give rise to risk.

1. Risk management process

1.1. Process

Risk management comprises the activities illustrated in Figure 1-1 below. Each of these activities is discussed in the following sections of this appendix.

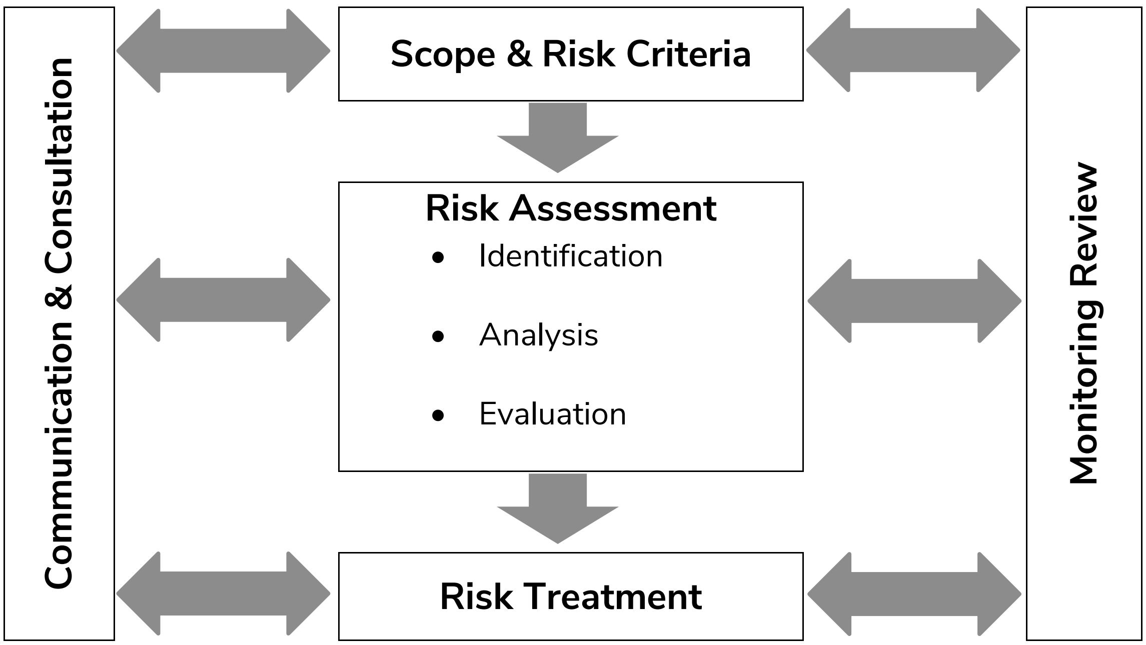

Figure E-1 Risk management process

1.2. Application

A proponent is required to perform risk assessments during the planning phase, the design stage of the development phase and the closure phase of the mine facilities described in the main document. The results of these assessments need to be included in the assessment and regulatory approvals documents and will be subject to review and comments by assessors, regulators, First Nations and other interested parties.

The proponent is required to refine the risk assessments as necessary based on reviews and comments by others and ensure the appropriate engineering and contingency measures, climate change adaptation measures and emergency response plans are put in place to reduce future risks and consequences of failures to acceptable levels. Furthermore, the proponent should continue risk evaluations and risk management during operations and closure to ensure risks remain acceptable utilizing "continuous improvement" or adaptive management approaches as necessary.

1.3. Communications and consultation

Communication and consultation with interested parties, regulatory agencies, the engineer of record (EOR) and the independent review board (IRB) should take place as described in Sections 2.0 to 5.0 of the main document. The mining company should provide plans for communication and consultation at an early stage to ensure that those accountable for implementing the risk management process, and those who are reviewing and commenting on it, understand the basis for the analyses, risk management decisions made and why particular actions are required.

Communication and consultation with interested parties is important as these parties have their own judgements about risk based on their knowledge, values and perceptions of risk. As the views of interested parties can have a significant impact on decisions made, their perceptions should be identified, recorded and taken into account. Communication and consultation should facilitate truthful, relevant, accurate and understandable exchanges of information, taking into account confidentiality and personal integrity.

1.4. Scope and risk criteria

The scope of the risk management process will vary based on the phase of mining and type of facility being considered, as well as the facility classification of the facility as described in Section 2.2 of the main document. The scope will typically include:

- a description of the phase (e.g. planning or development) and facility (e.g. tailings management facility) to be assessed;
- a description of the potentially effected human health and safety, land-use, natural, cultural and socio-economic environments;
- consideration of how climate change may introduce new risks, or modify existing risks;
- objectives of the risk management activities;

- responsibilities for conducting the risk assessment;
- responsibilities for developing risk treatments; and
- identification of the necessary supporting information, studies and levels of engineering design.

The company should define the criteria to be used to evaluate significant risk at the beginning of the process. Applicable legal and regulatory requirements should be included in the criteria as appropriate. The criteria should be continually reviewed and refined as necessary during the communication and consultation process.

In defining risk criteria, consideration should be given to the following:

- the nature and types of failures and consequences that can occur and how they will be measured;
- how likelihood will be defined;
- the timeframes of the likelihood and consequences;
- how the probability of failure is to be determined;
- defining criteria to allow the climate change risks to be differentiated (i.e, so all climate change risks do not end up in the same category);
- the views of the Government of Yukon and interested parties;
- the level at which the risk rating (combination of failure risk and consequence) becomes acceptable or tolerable; and
- whether combinations of multiple causative events should be taken into account and, if so, how and which combinations of these should be considered.

1.5. Risk assessment

The risk assessment process should include identification of risks, an analysis of these risks, their effects and consequences, and an evaluation of the need for risk treatment. These three aspects are discussed further below.

It is essential that appropriately experienced personnel undertake the risk assessment. They should not only have the academic training necessary to understand what risks could potentially occur, but also sufficient practical experience to understand scientific uncertainties and the effect of human behavior on risks. The designers of the facilities being analysed should not lead or perform the risk assessment but may assist the risk assessment team and provide background information, explain the basis of the design analyses and provide other pertinent information.

1.5.1. Risk identification

The sources of risk, areas of impacts, events (including changes in circumstances) and their causes and potential consequences should be identified. Comprehensive identification is critical because if a risk is not identified it will not be included in the analysis or evaluations.

Identification should include risks whether or not their source is under control of the mining company. Reasonable future mine site uses should be anticipated. Risks should include "knock-on" effects of particular consequences, including cascading and cumulative effects. All significant causes and consequences should be considered.

Identification should include risks that occur as a result of climate change vulnerabilities. Climate change vulnerabilities are present when a climate variable such as temperature or precipitation interacts with mine infrastructure in a manner that has the potential to give rise to risk.

1.5.2. Risk analysis

Risk analysis involves developing and understanding of the risk and provides input to risk evaluation and decisions on whether risks need to be treated. It involves consideration of the causes and sources of risk, their consequences and the likelihood of those consequences occurring. While consequences can be either negative or positive, generally only the negative consequences should be considered. Existing risk controls and their effectiveness and efficiency should be taken into account.

The confidence in determining the level of risk and its sensitivity to preconditions and assumptions should be considered in the analysis and communicated effectively to the mining company's decision-makers, regulators and interested parties. Divergence of opinion among experts, uncertainties, availability and quality of information, and limitations to calculations or modelling should be stated.

The risk analysis shall be conducted as described in Section 4.0 of this appendix, which includes a range of optional techniques. The type of assessment and the level of detail shall be performed as described in the main document.

Companies may use alternative techniques to those outlined in this appendix, provided these are approved by assessors and regulators.

1.5.3. Risk evaluation

The purposes of risk evaluations are to assist in making decisions, based on the outcomes of risk analysis, about which risks need treatment and the priority for treatment implementation.

Risk evaluation involves comparing the level of risk found during the analysis process with the established risk criteria that are developed as described in Section 3.4. Based on this comparison, the need for treatment can be considered.

In some circumstances, the risk evaluation can lead to a decision to undertake further analysis. The risk evaluation can also lead to a decision not to treat the risk in any way other than maintaining existing controls. This decision will be influenced by the risk attitude of the stakeholders and the government established during the consultation process, as well as that of the mining company.

1.6. Risk treatment

Risk treatment includes one or a combination of the following approaches that either reduce the likelihood, reduce the consequences of the risk selected for treatment or both:

- changes to the location or geometry of the facility;
- changes to the engineering design criteria of the facility;
- changes to the design or construction specifications of a facility;
- changes to the reclamation and closure plan;
- changes to the surveillance and monitoring systems and plans;
- changes to the operations of a facility;

- climate change adaptation measures or adaptation pathways to increase infrastructure resilience to future climate change;
- physical (e.g. providing barriers), or institutional (e.g. land use restrictions) controls to limit or prevent human or animal access to specified areas;
- training and operational plans to modify human or animal behaviours;
- contingency measures to be implemented as necessary to prevent a risk from occurring or to limit its consequences;
- emergency response plan to reduce the risk consequences;
- management and control systems; and
- others.

Selecting the most appropriate risk treatment options should be focused on reducing the risk ratings to acceptable levels as determined during the consultation process with stakeholders and the Government of Yukon, as well as levels acceptable to the mining company. In evaluating various options consideration can be given to balancing the costs and efforts of implementation against the benefits derived, with regard to human health and safety, cultural and community resources, the natural environment and land uses, legal and regulatory requirements and financial costs.

Documentation of the risk treatment measures should include, as appropriate:

- reason for selecting the treatment options;
- how the selected option will modify the likelihood and consequence;
- those accountable for approving and implementing the option;
- the proposed actions and their impacts on reducing the risk ratings;
- future event thresholds, at which point treatment measures are implemented (for example, if ambient temperatures reach at pre-defined trigger, a climate change adaption measure is implemented);
- resource requirements;
- performance measures and constraints;
- reporting and monitoring requirements; and
- implementation timing and schedule.

1.7. Monitoring and review

As appropriate, monitoring and review of implemented risk treatment measures should be conducted to assure their continued effectiveness. For example, measures such as design changes will require limited monitoring, whereas changes to operations plans or access controls will need ongoing monitoring and review.

Those measures requiring monitoring and review should be identified as such, and the monitoring and review requirements should be incorporated in various operational and environmental management plans required at a mine site. Any that cannot be accommodated in the mine's existing plans will require separate plans to be developed and approved.

2. Recommended risk assessment techniques

IEC 31010:2019 describes 31 different tools and techniques for conducting risk assessments. The most appropriate and the tool frequently used in Canada is referred to as the failure modes effects analysis. This is the main method selected and adapted for the Yukon in this appendix. Aspects of previous risk assessment work performed in Canada are also incorporated.

In addition to the above, provision is made for an initial identification and screening of all potential risks, referred to as a preliminary hazard assessment (PHA). This process has been added to ensure no potentially important risks are omitted. The screening is used to select those risks that need to be carried forward to the more detailed FMEA.

Finally, provision is also made for conducting more detailed risk analyses using an event tree analysis (ETA). This analysis is used to evaluate the risks and likelihood of failures specifically for water retaining embankments and spillways that remain in place during the long-term closure stage. As described in Section 3.0, this type of more detailed analysis is required for assessing the long-term adequacy of these important components.

Mining companies may select other techniques from the list contained in IEC 31010:2019 or others, provided they can demonstrate the techniques are as effective as a FMEA or an ETA and there are unique circumstances that justify the other approach. Alternative techniques require the approval of the Government of Yukon.

In summary, the following assessment approach is required.

- **Risks identification and screening** – this is a required pre-curser to the FMEA and is to be conducted in accordance with the IEC 31010:2019 Preliminary Hazard Analysis (PHA) described in Section 5.0 below.
- **Failure mode effects analysis (FMEA)** – as described above and in Section 6.0 below. Provision is also made for two types of FMEAs. The first is referred to as a qualitative approach, the second is referred to as a quantitative approach as discussed in Section 6.1. The relevant main document sections and Table 3-2 should be consulted as to the applicability of these two approaches.
- **Event tree analysis (ETA)** – as described above and in Section 7.0 below.

3. Risk identification and screening

3.1. Overview

Risk identification and screening, or a PHA, is a simple, inductive method of analysis whose objective is to identify the risks, consequences and events that can cause harm for a given activity, facility, component of a facility, or a process or system, and to select those risks requiring further analysis.

3.2. Inputs

Inputs include:

- information on the facility, component, system or process to be assessed;
- information on the environment surrounding the facility, including land use, cultural and environmental resources, infrastructure, etc; and

- information on current climate and future projected climate conditions.

3.3. Process

A list of risks and consequences should be formulated by the following activities:

- define the scope and objectives of the risk assessment;
- assemble a suitably qualified team for both the PHA and FMEA;
- understand the facility/process/operations to be subjected to the FMEA;
- break down the facility/process into its components and the operations into the associated steps or phases;
- define the function of each component or phase;
- identify the materials to be handled, used or produced and their reactivity;
- identify equipment to be employed;
- evaluate the layouts and engineering design;
- consider the physical and geochemical properties of the mined and processed materials and water;
- identify the climatic assumptions considered for design purposes (e.g. storm return periods, intensity-duration-frequency estimates);
- assess the affect of a future changing climate on the climatic design assumptions and how these design criterial incorporate the climate projections;
- assess the potential for construction defects, including consideration of the amount and reliability of the information used to characterize the strength of the foundations and facility structures (e.g. dams);
- determine the amount of water storage and handling;
- assess the interfaces among facility components;
- consider the degree of construction and operational oversight and management; and
- take into account experience at other similar facilities, etc.

Hazards are included in the PHA since it ensures that a wide net is cast to cover potential risks. For example, overtopping of a tailings management facility would be considered a hazard and should be included in the hazard and risk list mentioned below, even if the tailings are proposed to be deposited in an open pit.

A qualitative analysis is then performed considering both the likelihood and consequences of the identified hazards and risks, such as in the above case overfilling the pit or a pit slope failure. Based on this analysis, this pit disposal example may be considered too trivial to require further attention. The risks that need to be identified for further evaluation and carried forward to the FMEA stage are those risks considered important to the participants, and potentially requiring risk treatment.

Consideration should be given to how future climate change could modify identified risks.

It is important that the list of hazards and risks be as comprehensive as possible and that the selection of those requiring a FMEA is clearly explained. The list of risks considered, the criteria for selecting those for further analysis and the results of this selection should be described in the risk assessment documentation.

3.4. Outputs

Outputs include:

- a list of hazards and risks considered;
- criteria used to screen the hazards and risks; and
- a list of those hazards and risks requiring further analysis.

3.5. Strengths and limitations

The strengths and limitations of the method need to be taken into account when conducting the risk identification and screening. Strengths include:

- that it is able to be used when there is limited information; and
- it allows risks to be considered very early in the system lifecycle.

Limitations include:

- a PHA provides preliminary information; it is not comprehensive, neither does it provide detailed information on risks and how they can best be minimized or prevented.

4. Failure modes effects analysis

4.1. Overview

FMEA is a technique used to identify the ways in which components, systems or processes can fail to fulfill their design, operational of closure intent. A FMEA identifies:

- the mechanisms and the effects of failure of those hazards and risks identified during the PHA as requiring further analysis;
- the likelihood of the failure modes;
- the consequences of these failures to human health and safety, on cultural or community resources, natural environment and land use, legal and regulatory ramifications as well as the cost of remediation.
- methods and approaches that can be used to prevent the failures, or mitigate or avoid the consequences of the failures on the system; and
- the rankings of each failure mode identified, according to its importance or criticality.

A FMEA can be either qualitative or semi-quantitative. In both cases, the likelihood and consequences are determined and combined to develop a risk rating. In the case of a qualitative analysis, the likelihood is expressed as a numeric probability but is estimated by the risk assessor using knowledge of the design and design criteria, proposed operational procedures and resources, and professional judgement. A fully quantitative analysis, on the other hand, would require modeling of the systems behaviour or recourse to research and published information on failure statistics. A semi-quantitative analyse as described here is a combination of both qualitatively assessed and quantitatively determined likelihoods and consequences. For the sake of convenience, it is referred to herein as a quantitative analysis.

Quantitative assessments as described in these guidelines will usually only be required for Class III risk facilities (See Section 2.0 and Table 2-1 of the main document) and for those risks where it is both important to establish an accurate likelihood and for which the consequences are extreme. Examples of where quantitative assessments of likelihood may be necessary include hydrology studies and modelling to assess the likelihood of overtopping of a TMF embankment causing a release, or where potential cascading effects need to be considered such as the level of the solid tailings, the amount of water that can be stored, the spillway design capacity and the nature of the dam crest, which determines its vulnerability to erosional damage caused by overtopping.

As far as assessing the severity of the consequences of a risk, the qualitative approach involves using realistic hypotheses of the effects, simple calculations and judgement to assess the consequences. An example would be assessing what the consequence of a tailings release may be. The approach used would consider the order of magnitude of the volume of tailings that could be released and compare it to the size and extent of any rivers and lakes downstream to assess the likely consequences. A quantitative analysis of consequences, on the other hand, would require a dam breach analysis using established computer models to estimate the volume of tailings likely to be released, the downstream distance over which they would be deposited their lateral spread, as well as the maximum elevation of released tailings and water along the downstream river reaches.

4.2. Inputs

A FMEA requires information about the elements of the system in sufficient detail for a meaningful analysis of the ways in which each facility or component can fail. Failures should be detailed at the individual component level for facilities such as a TMF.

Information required typically includes:

- drawings or a flow chart of the facility being analysed and its components, and the steps of an operational process;
- design criteria and standards and the proposed operating procedures;
- an understanding of the function of each step of a process or component of the system;
- details of environmental (such as climate) and other parameters, which may affect operations;
- an understanding of what effects climate change will have on the risks and consequences, and taking these into account if necessary;

- an understanding of the consequences of particular failures; and
- historical information on failures including failure rate data where available.

4.3. Process

The FMEA process includes the following steps:

- complete the PHA as described above;
- for every component or operating phase listed, identify in more detail than for the PHA:
    - How can each part conceivably fail?
    - What mechanisms might produce these modes of failure?
    - What could the effects be if the failures did occur?
    - Is the failure harmless or, if damaging, how damaging?
    - How is the failure detected?
- identify inherent provisions in the design and operations procedures to compensate for the failure;
- describe the failure modes;
- establish the likelihood of each of the failure modes as described below;
- establish the consequences of each failure mode using the guidelines below;
- establish a risk rating for each of the identified failure mode; and
- establish risk treatments for the higher rated risks as described below.

The following likelihood scale (Table E-2) should generally be used. It is important to note that lower probabilities of failure for each likelihood category are assigned to risks to human health and others such as risks to land-use, natural, cultural and socio-economic environment.

Table E-2 Likelihood scale

TABLE E-2 LIKELIHOOD SCALE			
LIKELIHOOD CATEGORY	DESCRIPTIONS	PROBABILITY FOR PERIOD CONSIDERED	
		RISK TO HUMAN HEALTH AND SAFETY	OTHER RISKS
Not likely (NL)	The physical conditions do not exist for its development or the likelihood is so remote as to be non-credible.	<0.01% (up to one-in-10,000)	<0.1% (up to one-in-1,000)
Low (L)	The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred in the past or that a condition or flaw exists that could lead to it developing in the future.	0.01% to <0.1% (to one-in-1,000)	0.1% to 1.0% (to one-in-100)
Moderate (M)	The defect may occur but failure is considered to be unlikely.	0.1% to 1.0% (to one-in-100)	1.0% to 10.0% (to one-in-10)
High (H)	The fundamental condition or defect is known to exist or indirect evidence suggests it is plausible, but evidence is not weighted toward likely.	1.0% to 10% (to one-in-10)	10% to 50% (to one-in-2)
Expected (E)	There is direct evidence or substantial indirect evidence to suggest it has occurred or is likely to occur.	>10% (greater than one-in-10)	>50% (greater than one-in-2)

When using the above table, it is important to understand that the probabilities apply to the period under consideration. For example, if the annual failure probability is 1%, then during an operating period of 10 years the probability of failure would be approximately 10%. However, during a post-closure period of 100 years the probability would be approximately 63%[1]. (Table E-1.)

[1] Using the encounter probability formula, encounter probability $1 - \left(1 - \frac{1}{T}\right)^{P}$, where T = return period in years and P = period for which the risk is being assessed.

When considering the probability of failure for facilities or components designed for the probable maximum flood (PMF), it is permissible to use an annual probability of 0.001% or a return period of 1 in 100,000 years.

The next part of the analysis is to assess the severity of the consequence of the failure. This should be done with the aid of Table E-3 below. In assessing consequences, the following categories should generally be considered:

- human health and safety;
- cultural and community resources;
- natural environment and land uses;
- legal and regulatory requirements; and
- costs of remediating the consequence.

Table E-3 below summarizes the consequences for each of the above categories and for five different consequence scales. This table serves as a guideline and can be adapted to specific site conditions as necessary. For the purposes of the qualitative analysis, the most significant consequences are assessed and used in the analysis. For example, if the consequences to the environment are considered to have the highest consequence scale then that consequence scale is used in the analysis.

For quantitative risk assessment, generally, all five consequence categories will be analyzed and reported.

Table E-3 Severity of consequences

Table E-3 Severity of Consequence					
Consequence Severity Category	Human Health and Safety	Cultural and Community Resources	Natural Environment and Land Use	Legal and Regulatory	Physical Remediation Cost Implications (excluding fines and compensation payments)[2]
Extreme (E)	Fatality or multiple fatalities expected	First Nation and local community, international and non-governmental organization (NGO) outcry and demonstrations, results in large stock devaluation to the company; severe restrictions of 'license to practice'; large compensatory payments etc.	Catastrophic impact on habitat (irreversible and large)	Unable to meet regulatory obligations; shut down or severe restriction of operations	Would result in an extreme impact on business function. May not be possible to recover from, and could result in complete or partial loss of value in the asset.
High (H)	Severe injury or disability likely; or some potential for fatality	First Nation and local community, international or NGO activism results in political and financial impacts on company's and in major procedure or practice changes	Significant impact on habitat (irreversible and significant)	Regularly (more than once per year) or severely fails regulatory obligations or expectations – large fines and loss of regulatory trust	Would result in a significant impact on business that would be difficult to recover from.
Moderate (M)	Lost time or injury likely; or some potential for serious injuries; or small risk of fatality	Occasional First Nation, community, international and NGO attention requiring minor procedure changes and additional public relations and communications	Significant, reversible impact on habitat	Occasionally (less than one per year) or moderately fail regulatory obligations or expectations - fined and/or censure	Would result in a significant impact on business performance. Recovery is possible in near-term.
Low (L)	First aid required; or small risk of serious injury	Infrequent First Nation, community, international and NGO attention addressed by normal public relations and communications	Minor impact on habitat	Seldom or marginally exceed regulatory obligations or expectations. Some loss of regulatory tolerance, increasing reporting.	Would result in a low impact on business performance, inconvenient but manageable.
Negligible (N)	No concern	No First Nation, community, international, or NGO attention	No measurable impact	No regulatory obligations or expectations exceeded	Considered a normal day-to-day event, no impact to business function.

[2] An absolute threshold dollar figure was not used in Table E-3 as the material costs to one company are vastly different to another. Proponents are expected to develop a cost threshold that is consistent with the impacts to business performance described in the table.

The likelihood and consequence are then combined into a risk rating matrix as shown in Figure E-2 below.

Likelihood

Consequence Scale	Not likely	Low	Moderate	High	Expected
Extreme	II	II	I	I	I
High	III	III	II	II	I
Moderate	V	IV	III	II	II
Low	V	V	IV	III	II
Negligible	V	V	V	IV	III

Figure E-2 Likelihood

Failure modes that are plotted in the extreme top right-hand corner have the highest risk rating (e.g. I), while those in the bottom left-hand corner have the lowest risk rating (e.g. V). The risk rating numbers shown on the matrix are used to indicate what risk treatment measure should typically be considered for specific failure modes. High consequence modes are considered more serious than low consequence modes of the same the same likelihood, hence the skewing of the risk rating numbers and colours.

The general risk treatment requirements for each of the risk ratings are provided in Table E-4 below.

Table E-4 Requirements for various risk ratings

Table E-4 Requirements for Various Risk Ratings	
Risk Rating	**Risk Treatment Requirements**
I	Risks in this category are generally not acceptable and require implementation of measures to reduce both the consequences and the likelihood of the failure.
II	Risks in this category are generally not acceptable unless the mining company can demonstrate all reasonable treatment measures have been implemented, there are suitable contingency plans that continue to minimize risks, and emergency response plans to minimize the consequences should failure occur.
III	Reasonable risk mitigation measures need to be considered and implemented as appropriate, in order to reduce these risks.
IV	Risks require careful monitoring for use in ongoing verification of the risk rating.
V	Generally acceptable risks.

Numerical weights can also be assigned to both the likelihoods and consequence severities. These weights are then multiplied to provide for a numeric risk rating which in turn is used to rank the risks and assess the need for treatment measures. This process provides the same results as the above matrix approach but allows the calculations of the risk ratings and the ranking of these to be automated, which may be important when there are a large number of risks being analyzed.

The weights listed in Tables E-5 and E-6, below, are recommended. Alternative scales for both likelihood and consequences can be proposed if necessary to more accurately reflect site conditions.

Table E-5 Likelihood numeric weights

Table E-5 Likelihood Numeric Weights	
Likelihood Category	**Numeric Weight**
Not likely (NL)	0.01
Low (L)	0.1
Moderate (M)	1
High (H)	10
Expected (E)	100

The following weights are recommended for the consequence severities.

Table E-6 Consequence severity numeric weights

Table E-6 Consequence Severity Numeric Weights	
Consequence Category	**Numeric Weight**
Negligible (N)	1
Low (L)	20
Moderate (M)	400
High (H)	8000
Extreme (E)	160,000

Using the above numeric approach to calculating risk ratings, the following (Table E-7) risk rating definitions apply:

Table E-7 Risk ratings

Table E-7 Risk Ratings	
Risk Rating	**Numeric Risk Rating (Likelihood Weight x Severity Weight)**
I	>100,000
II	1,000 to 100,000
III	50 to 1,000
IV	10 to 50
V	<10

Once failure modes and mechanisms are identified, risk treatment methods should be developed in accordance with the requirements outlined in Table E-4 and as discussed in Section 8.0 below. In the event risk treatment measures involve design or operational changes, the risk ratings for those failure modes should be re-assessed.

5. Event tree analysis

5.1. Overview

An event tree analysis (ETA) is a graphical technique for representing mutually exclusive sequences of events following an initiating event according the functional effectiveness of the various systems designed to provide for safe operation of the component such as a dam or a spillway. It can be applied both qualitatively and quantitatively. For purposes of this appendix, a quantitative approach is recommended and described.

5.2. Input

Inputs include:

- a list of appropriate initiating events;
- information on the types of failures and the consequences of these, and their failure probabilities; and
- understanding of the process whereby an initial failure escalates.

Typical initiating events and the associated failure scenarios for a spillway are listed in Table E-8 and for a dam in Table E-9. These should be accommodated in the ETA as well as others that are identified.

Table E-8 Spillway failure initiating events

TABLE E-8 SPILLWAY FAILURE INITIATING EVENTS		
INITIATING EVENTS	**FAILURE SCENARIOS**	**OUTCOMES**
• Large storm event • Landslide into spillway channel • Changes in design flood magnitudes (more data available)	• Erosion • Blockage	• Dam overtopping and failure • Erosion causes release of tailings and water • Dam failure

Table E-9 Dam failure initiating events

TABLE E-9 DAM FAILURE INITIATING EVENTS		
INITIATING EVENTS	**FAILURE SCENARIOS**	**OUTCOMES**
• Seismic events • Weathering of structural fill • Blockage of drains in dam (geochemical or biological) • Increasing foundation temperatures • Overestimated foundation strength • Operational dam construction material strength • Construction inadequacies • Changes in design flood magnitudes (more data available)	• Settlement • Slumping • Slope failure	• Dam overtopping and failure • Dam failure

5.3. Process

The following steps need to be carried out:

- define the scope and objectives of the ETA;
- assemble a suitably qualified team experienced in the design, construction and operation of large dams and familiar with the geologic conditions at the mine site;
- understand the design and operational performance of closure facilities and components to be subjected to the ETA;

- evaluate the layouts, engineering designs, construction specifications, as-built drawings and QA/QC construction records;
- consider the physical and geochemical properties of the dam and spillway construction and underlying geological materials;
- consider the long-term operations for the facilities or components including the frequency of use, the intensity of the seismic and hydrologic design events and the anticipated amount of post-closure care and maintenance; and
- take into account experience at other similar facilities, etc.

The event tree starts by selecting an initiating event, such as those shown in the first column of Tables E-8 and E-9. Functions or systems, which are in places to mitigate outcomes, are then listed in sequence. For each function or system, a line is drawn to represent their success or failure. A particular probability of failure should be assigned to each line, with this conditional probability estimated by expert judgement or further more detailed analyses. In this way, different pathways from the initiating event are modeled.

Note that the probabilities on the event tree are conditional probabilities. For example, the probability of a dam slope being sufficiently strong is not the first probability obtained from the classical dam stability analyses under design conditions, but, for example, the probability under conditions where drains are blocked or partially blocked and the occurrence of a seismic event.

Each path through the tree represents the probability that all of the events in that path will occur. Therefore, the frequency of the outcome is represented by the product of the individual conditional probabilities and the frequency of the initiating event, given that the various events are independent.

A simplified example of a typical ETA for a spillway is provided in Figure E-3 below.

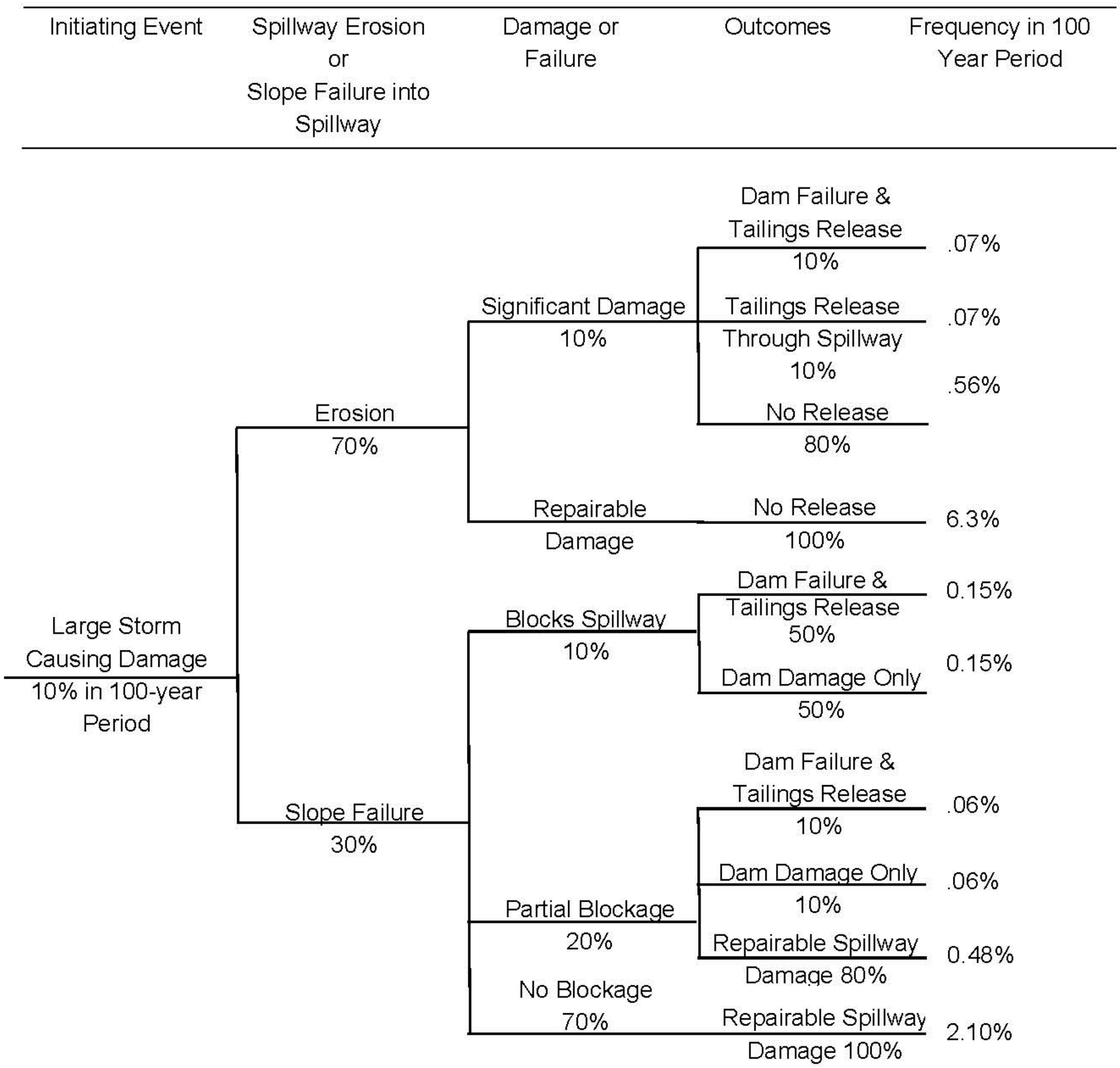

Figure E-3 Example event tree for a spillway

Use the FMEA Tables E-2 through E-7 and Figure E-3 augmented by Table E-9 and E-10 to assess the risk rankings for the individual failure modes and as illustrated in the example shown in E-3. As illustrated below use the ETA to identify and describe individual similar failure mode and develop appropriate risk ratings and risk treatments for each.

Table E-10 provides for an additional consequence category that takes into account the undesirability of having to rely on damage repairs or reconstruction during the post-closure stage. As shown by the example in Table E-10, there are several cases where the consequence severity rating is increased over those determined using Table E-4.

Table E-10 Additional consequence category for closure ETA

Table E-10 Additional Consequence Category for Closure ETA	
Consequence Severity Category	**Facility Damage**
Extreme (E)	Reconstruction of all or portions of the dam or spillways are required.
High (H)	Major repairs to the dam or spillways are required.
Moderate (M)	Minor event specific repairs are required for the dam or spillways.
Low (L)	Routine predictable repairs required (can be considered as maintenance as needed).
Negligible (N)	No repairs required.

Table E-11 Example of an event tree analysis

Table E-11 Example Results of an Event Tree Analysis						
Outcome	Likelihood in a 100-year Period (Derived from the individual branches in the ETA tree – Figure E-3)	Likelihood Rating		Consequence Severity		Risk Rating
		Risk to Human Health and Safety	Other Risks	Based on Table E-4	Modified Based on Table E-9	Based on Highest Consequence Severity & Likelihood Ratings
Dam failure accompanied by a tailings release	0.28% (0.07+0.15+0.06 above)	Moderate	Low	Extreme	Extreme	III
Tailings release	0.07%	Low	Negligible	Moderate	High	IV
Damage to the dam	0.21% (0.15+0.06 above)	Moderate	Low	Low	Moderate	IV
Repairable damage to the Spillway	9.44% (6.3+0.56+0.48+2.10 above)	Low	Moderate	Low	Moderate	IV

6. Risk treatment

6.1. For preliminary hazard assessments and failure modes effects analysis

In the event there are unacceptable risks requiring mitigation as determined by the risk ratings, treatment measures need to be developed. It is also important to identify whether the risk mitigation measures reduce either the likelihood or the consequence ratings, or both. As discussed above, the risk assessment then needs to be repeated incorporating these mitigation measures to demonstrate acceptable risk ratings can be achieved.

Risk treatment methods need to be developed as required by Table E-4. The following level of detail needs to be provided for each of the following potential risk treatment methods:

Design changes: Revised drawings, and specifications as necessary, need to be prepared to demonstrate the feasibility of the changes.

Operational changes: Revised conceptual or detailed operations plans, as appropriate, need to be provided. During the assessment stage, conceptual plans would generally be required, while during the regulatory approvals and later stages, detailed plans would be required.

Contingency measures and plans: Either revised or new plans need to be prepared to either a conceptual or detailed level as necessary.

Emergency response plans: Emergency response plans need to be revised to incorporate the results of the FMEA or, if existing, revised as necessary.

6.2. For event tree analysis

Specifically for the embankments and spillway components of a TMF or a water retaining dam that has been subjected to an ETA, should there be a need for risk treatment, this should generally include either increasing the robustness of the components or their redundancy as discussed in Section 4.3.6 of the main document. The preferred risk treatment approach is therefore:

Design of additions or modifications to the dam and/or spillway: Drawings, specifications and construction schedules need to be prepared to demonstrate the feasibility and constructability of the changes and additions. These measures would generally need to be installed during the active closure stage.

Where appropriate and with the approval of regulators, other typical risk treatments, such as those described below, can be provided.

Changes to the long-term care and maintenance program: Revised detailed plans need to be provided. Methods of providing financial assurances for funding the long-term care and maintenance also need to be described and implemented.

Contingency measures and plans: Either revised or new plans need to be prepared to either a conceptual or detailed level as necessary. Methods of providing financial assurances for funding contingency measures need to be described and implemented.

Emergency response plans: Emergency response plans need to be revised to incorporate the results of the FMEA or, if existing, revised as necessary. Methods of providing financial assurances for funding emergency measures need to be described and implemented.

7. Outputs

7.1. Failure modes effects analysis

The primary output of FMEA is a list of failure modes, the failure mechanisms and effects for each component or step of a system or process (which may include information on the likelihood of failure). Information is also given on the causes of failure and the consequences to the system as a whole. The output from FMEA includes a rating of importance based on the likelihood that the system will fail, the level of risk resulting from the failure mode or a combination of the level of risk and the detectability of the failure mode.

The FMEA is then documented in a report that contains:

- details of the system that was analysed;
- the way the exercise was carried out;
- assumptions made in the analysis;
- sources of data;
- the amount of, and the results from, consultation with interested parties;
- the results, including the completed worksheets and any changes to the risk ratings resulting from design or operational changes identified as part of the FMEA. Note that these changes in risk ratings only need to be documented once. In the event the FMEA is updated at a later stage or phase it can be conducted incorporating these and any other changes that may have been implemented;
- the criticality (if completed) and the methodology used to define it; and
- any recommendations for further analyses, design changes or features to be incorporated in test plans, etc.

The system may have to be reassessed by another cycle of FMEA after the actions have been completed.

7.2. Event tree analysis

The primary outputs from an ETA include the following:

- qualitative descriptions of potential problems as combinations of events, producing various types of problems (range of outcomes) from initiating events;
- quantitative estimates of event frequencies or probabilities and relative importance of various failure sequences and contributing events;
- descriptions of the recommendations for reducing risk ratings; and
- quantitative evaluations of the effectiveness of the recommendations.

8. Strengths and limitations

The strengths and limitations of the methods used should be considered when performing the analyses and discussed in the reporting of the results.

The strengths of FMEA are as follows:

- widely applicable to human, equipment and system failure modes and to hardware, software and procedures;
- identifies component failure modes, their causes and their effects on the system, and presents them in an easily readable format;
- avoids the need for costly equipment modifications in service by identifying problems early in the design process;
- identifies single point failure modes and requirements for redundancy or safety systems; and
- provides input to the development monitoring programs by highlighting key features to be monitored.

Limitations include:

- can identify only single failure modes, not combinations of failure modes;
- unless adequately controlled and focused, FMEA studies can be time consuming and costly;
- tends to rate rare but extreme events as low risks, which may not be consistent with expectations of the stakeholders; and
- can be difficult and tedious for complex multi-layered systems.

Strengths of ETA include the following:

- displays potential scenarios following an initiating event and the influence of the success or failure of mitigating systems or functions in a clear diagrammatic way; and
- accounts for timing, dependence and domino effects, and it graphically represents sequences of events.

Limitations ETA include:

- in order to use ETA as part of a comprehensive assessment, all potential initiating events need to be identified. This requires input from experienced risk assessment and design and construction engineers.

- With event trees, only success and failure states of a system are dealt with, and it is difficult to incorporate delayed success or recovery events; and
- Any path is conditional on the events that occurred at previous branch points along the path. Many dependencies along the possible paths are therefore addressed. However, some dependencies, such as common components, may be overlooked if not handled carefully, which may lead to optimistic estimations of risk.

9. References

International Organization for Standardization. 2019. Risk Management – Risk Assessment Techniques (IEC 31010:2019)

International Organization for Standardization. 2018. Risk Management – Principals and Guidelines (ISO 31000:2018)

Appendix F
Construction Plans

February 2023

Yukon

Table of contents

1. Introduction

Construction plans must be provided for all retaining, contact and non-contact water conveyance facilities that are part of a mine waste management facility. Plans should be revised and updated for any raises or expansions of water retaining or containment facilities. Construction plans must describe construction management and supervision, sequence/schedule, temporary facilities, environmental management, quality assurance/quality control, emergency management, change management and requirements for commencing operations. Details about each of these requirements are described in the following sections.

2. Construction management and supervision

The construction management organization and responsibilities must be adequately described so as to identify the reporting relationships (provide organization chart) and responsibilities for all key participants. Procedures for communication between the owner, the design team and the construction team must be included.

2.1. Owner

The owner must demonstrate commitment to construct facilities in accordance with designs and has overall responsibility for ensuring that the construction achieves the requirements of the design. The owner is responsible for engaging a qualified engineer of record (EOR), construction manager and QA/QC monitor, and providing these officials with appropriate authorities to manage construction. The owner must provide sufficient resources to carry out the project in accordance with the design.

2.2. Engineer of record

The EOR must be independent from the owner and is responsible for confirming that the construction achieves the design and its specifications. Changes to designs or design specifications can only be made with the written approval of the EOR.

2.3. Construction manager

The construction manager is responsible for directing the construction activities in accordance with the design, and any direction from the EOR. The construction manager must report any proposed changes to the EOR and receive written approval before proceeding with changes.

2.4. Quality assurance and quality control monitors

The quality assurance (QA) and quality control (QC) monitors are responsible for day-to-day monitoring of construction activities and performance with respect to specifications. The monitors must be independent from the owner and the construction forces and have a direct reporting relationship to the EOR. The monitors must have authority to direct the construction forces to remediate conditions that do not meet design specifications. Only the EOR should have authority to overrule decisions of the monitors with respect to compliance with design specifications. In general, the QC monitor works for the contractor, while the QA monitor works for the owner.

2.5. Environmental monitor

The environmental monitor is responsible for implementing the environmental monitoring plan and must have authority to direct construction forces to take action to address unacceptable environmental conditions caused by construction activities.

3. Construction sequence and schedule

The construction sequence and schedule must be described, including specific tasks and their timing, and any linkages between tasks. Include sequence and schedules for any temporary facilities that are required to facilitate construction or interim facilities that are required between construction stages. Implementation of environmental management plans should be addressed in the sequence and schedule. In cases where mining or processing are part of the construction[1] address the schedule and sequence for loading of ore on the pad or delivering waste rock to the construction area.

The schedule should describe timing and sequences for activities that are sensitive to seasonal conditions or other factors.

Provide Gantt charts or other figures to support the description of sequence and schedules.

4. Temporary and interim facilities

All temporary and interim facilities that will be associated with the construction of the mine waste management facility must be described. Temporary facilities are those that are established to facilitate construction activities only, for example, coffer dams or temporary diversions. Interim facilities are those that are established for the duration of a single stage of a project, for example, an interim spillway on stage 1 of a tailings dam. Provide designs for all temporary and interim facilities. If designs are provided in other documents, then references to those documents should be provided in the construction plan.

Identify design criteria for temporary and interim facilities and provide rationales for selection of the criteria. Design criteria should demonstrate appropriate management of risks during construction periods for temporary facilities and during expected life span for interim facilities. If the project will include a series of interim facilities, the selection of the design criteria must consider the combined life span of those facilities.

The minimum standards for flood routing for all temporary water conveyance and containment facilities are:

- conveyance of peak flows for design events with durations consistent with times of concentration for the contributing watersheds, or
- storage of volumes from the design events.

[1] e.g. stacking ore on the leach pad or using waste rock as construction material such as dam fill.

More stringent standards will often be required and strong rationale must be provided for applying these minimum standards.

5. Construction environmental management

Environmental management and monitoring approaches that will be taken during construction must be described. This should include identification of environmental objectives and criteria for the construction project as well as development of specific environmental management and monitoring plans as appropriate for the proposed construction activities.

5.1. Construction water management plan

The objectives of a construction water management plan are to keep non-contact water clean, and manage contact water to minimize effects on the environment. The facilities and activities for managing clean water, sediment laden water and chemically contaminated water during the construction period must be described. If facilities and measures are not proposed for chemically contaminated water, provide evidence to demonstrate why chemical contamination will not occur during construction. Demonstrate how the plan will achieve appropriate effluent quality standards and protective conditions in receiving waters.

- Apply the *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects* (Government of Yukon 2021)

5.2. Erosion and sediment control plan

The objectives of the erosion and sediment control plan are to minimize erosion associated with construction activities and control sediment release to the environment. Describe specific measures that will be taken to minimize erosion during each type of construction activity proposed. Describe facilities and approaches for sediment control, including design criteria and designs for constructed facilities. Identify points of discharge and provide evidence to demonstrate how the plan will achieve appropriate effluent quality standards and protective conditions in receiving waters

- Apply the *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects* (Government of Yukon 2021); and
- Apply the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME) guideline for Total Particulate Matter.

5.3. Construction environmental monitoring plan

The objective of construction environmental monitoring is to confirm environmental conditions and performance during construction activities. Appendix G provides additional guidance about environmental monitoring plans.

The plan should describe all environmental monitoring that will be undertaken during construction, including sampling, parameters, frequencies, methods, analysis and reporting. Monitoring should be included for all environmental components that may impact, or be affected by, the construction activities, for example meteorology, air quality, hydrology, water quality, wildlife, wildlife habitat, aquatic ecosystem and soil stability. The plan should describe how unacceptable environmental monitoring results will be addressed if caused by construction activities, including responsibilities, processes and reporting relationships.

6. Construction quality assurance and quality control

Provide details about the construction quality assurance program that will be implemented so that construction activities generate results that meet the design specifications. Also provide details about the construction quality control program that will confirm compliance with design specifications. Describe both management processes and testing activities that comprise the quality assurance and quality control program. For example:

- quality assurance and quality control testing and observation methods, including the types of tests, frequencies and acceptable results;
- handling of deficient materials identified by quality assurance testing, or deficient outcomes identified by quality control testing; and
- individuals responsible for overseeing the testing, and their authority for initiating responses. For example, the engineer of record and the QA/QC monitor and their teams must have final and conclusive authority to direct corrective actions.

Recognize that quality assurance testing, analysis and interpretation must take priority over construction activities, and the need to complete the required quality assurance actions may sometimes delay construction activities.

7. Construction emergency management

Provide an emergency preparedness plan (EPP) that describes actions that will be taken to respond to emergencies during the construction period. Include a spill contingency and response plan that describes actions and responsibilities for responding to spills of any hazardous materials that may be used during construction. Include plans for addressing extreme events like floods and forest fires. Also describe plans for addressing malfunctions and accidents. Risk assessment processes may be used to characterize events that should be addressed in the EPP.

8. Change management

Describe the processes that must be followed, and approvals required for any changes to the design or design specifications. All changes must be approved in writing by the EOR and agreed to by the owner.

9. Commencement of operations

Describe the processes that must be followed and approvals required before commencement of operation of the mine waste management facility as a whole, as well as for individual retaining, containment and conveyance components.

10. References

Canadian Council of Ministers of the Environment (CCME), 2002. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Total Particulate Matter.

Government of Yukon, 2021. Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects.

Appendix G
Environmental Monitoring Requirements

February 2023

Yukon

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1. Introduction

Monitoring of environmental conditions must begin as early as possible in project planning and continue through all phases and stages of the project – planning, development, operations and closure. Systematic monitoring programs should be designed to address current and expected future data and interpretation needs, and should be revised and updated as site or environmental conditions or concerns change.

A comprehensive environmental monitoring program needs to include measurements of environmental conditions in reference areas, exposed areas, internal areas and perimeter areas. Data from a range of locations and for a range of environmental components will be needed to support interpretation of results. Sampling intensity should be sufficient to support delineation of performance and effects between various mine components.

There are four main purposes of environmental monitoring:

1. <u>Baseline and site-characterization monitoring</u> to characterize conditions at the site, in all potentially affected areas and in reference areas before the onset of any project-related effects.
2. <u>Confirmation monitoring</u> confirms that environmental conditions are consistent with expectations developed during project planning.
3. <u>Performance monitoring</u> evaluates performance of site facilities, operations, and systems. It often includes compliance monitoring.
4. <u>Adaptive management monitoring</u> provides data to support decision-making about adaptive management responses.

Baseline and site-characterization monitoring requirements (item 1 above) are addressed in appendix A and B of the main document. Expectations for monitoring during operations and closure (items 2, 3 and 4 above) are described in this document.

2. Operational and active closure monitoring

Environmental monitoring requirements are likely to be most intense during the initial construction stage, operations phase and active closure stage of a mine project, because these phases usually include the most intensive site activities and associated potential for effects on the environment. While monitoring during active closure stage will be defined in a reclamation and closure plan (RCP), it will generally be a continuation of the operational monitoring program with refinements to address the changes in the types of activities occurring, contaminants of concern and extent of effective progressive reclamation.

Confirmation, performance and adaptive management monitoring are all important for making decisions about ongoing site activities during the operations phase and active closure stage. Monitoring data will be used to identify what variances from predictions are occurring and whether such variances require action to eliminate or minimize effects on the environment. The data will also be used to understand the extended concentration pathways (ECPs) post-2100 during interim care and maintenance and active-closure phases.

Table G-1 summarizes expected monitoring requirements for the operations phase and active closure stage, including the environmental components that must be monitored along with the type, location and frequency of monitoring. Specific types of monitoring may be removed, provided there is a strong rationale describing why that component is not relevant to a specific site or operation. Regulators may identify project specific monitoring requirements that are not identified in table G-1.

Table G- 1 Minimum Operational and Active Closure Monitoring

Table G-1 Minimum Operational and Active Closure Monitoring				
Environmental Component	**Type of Monitoring**	**Locations**	**Frequency**	**Purposes**
Surface water	Water quality and flow	Reference	Monthly	• Confirm reference conditions. • Understand project performance. • Interpretation of contaminant loading. • Water and load-balance development and refinement. • Identify environmental effects or trends. • Adaptive management response.
		Internal (e.g., pits and ponds)	Monthly	
		Discharge and seepage	Monthly, weekly or daily during discharge	
		Receiving	Monthly, or weekly during discharge	
Groundwater	Water quality and water level	Reference	With sufficient frequency to understand seasonality and characterize seasonal variability, at least quarterly	• Confirm reference conditions. • Understand project performance. • Interpretation of contaminant loading. • Water and load-balance development and refinement. • Identify environmental effects or trends. • Support mine component construction. • Adaptive management response.
		Internal (i.e., porewater)	Monthly to define seasonal variability, then quarterly	
		On-site	Monthly to define seasonal variability, then quarterly	
		Downgradient	Monthly to define seasonal variability, then quarterly	
Aquatic Ecosystem	Benthic and periphyton	Reference	Annual	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Exposed	Annual	
	Sediment quality	Reference	Annual	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	Annual	
	Fish usage	Reference	Annual	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	Annual	
	Contaminants in fish[1]	Reference	Annual	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	With sufficient frequency to understand conditions, no less than annual	
Air		Reference	Continuous for particulates to define variability	• Confirm reference conditions. • Understand project performance.
		Upwind		

TABLE G-1 MINIMUM OPERATIONAL AND ACTIVE CLOSURE MONITORING				
ENVIRONMENTAL COMPONENT	**TYPE OF MONITORING**	**LOCATIONS**	**FREQUENCY**	**PURPOSES**
	Air quality (dust, specific contaminants of concern, criteria air contaminants)	Downwind	Weekly 24-hour samples for metals to define variability. Intensive program to define hourly, daily and seasonal variability for criteria air contaminants (CACs). For areas more than 5 km from a community, monitoring may be reduced to two-day programs once per month for particulates, metals and CACs. For areas within 5 km of a community, continuous monitoring for particulates should continue throughout, along with weekly 24 hour samples for metals.	• Interpretation of contaminant loading and dust transport. • Adaptive management response. • Identify environmental effects or trends.
Meteorology	Temperature, precipitation, wind speed, wind direction, solar radiation, evaporation, snow accumulation and snow-water or ice-water equivalencies	On site, within watershed, at location selected to minimize local affects	Ongoing	• Understand ongoing climate conditions and trends. • Continued collection of climate observation to inform adaptation measures and updating projections as necessary. • Water management planning. • Water balance development and refinement.
Wildlife	Waterfowl use	Open water areas that contain mine affected water	Spring, summer, fall	• Adaptive management response. • Confirm environmental performance.
	Wildlife use	Mine site area and mine waste areas	Ongoing	• Adaptive management response. • Confirm environmental performance.
	Contaminants in wildlife	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Adaptive management response. • Identify environmental effects or trends.
		Mine affected areas	Every three years	
Vegetation	Contaminants in vegetation	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Adaptive management response. • Identify environmental effects or trends.
		Mine affected areas[1]	Annually for the first three years and every three years thereafter	

[1] Frequencies for monitoring of contaminant levels in fish and vegetation do not apply for uranium mining.

TABLE G-1 MINIMUM OPERATIONAL AND ACTIVE CLOSURE MONITORING				
ENVIRONMENTAL COMPONENT	TYPE OF MONITORING	LOCATIONS	FREQUENCY	PURPOSES
Terrestrial	Permafrost conditions (subsurface temperature monitoring, visual inspections)	On site and mine affected areas	Ongoing	• Provide information to update engineering design. • Adaptively manage on-site activities. • Minimize thawing and permafrost degradation wherever possible.
	Geohazards (landslides, slope failures, fluvial, permafrost, seismic)	On site and mine affected areas	Ongoing	• Identify risks to the project or environmental monitoring network. • Monitor areas of concern. • Adaptively manage on-site activities.

3. Post-closure monitoring

During the post-closure stage, the monitoring program design must consider the scope and scale of ongoing activities at the site. In general, monitoring requirements may be reduced once monitoring demonstrates that the closure methods and works are achieving predicted and acceptable performance outcomes on an ongoing and consistent basis. If the post-closure stage includes intensive active care measures the monitoring program for these components will be similar to that conducted during the operations phase and active-closure stage.

The focus of monitoring during the post-closure stage will be on environmental conditions in the exposed environment, but monitoring of environmental conditions in reference and internal areas will be necessary to support interpretation of results and application of adaptive management. Monitoring frequencies must be sufficient at the start of the post-closure monitoring to demonstrate stable conditions and understand seasonal and inter-annual variability. Once the monitoring results confirm that environmental conditions are acceptable, stable and within project expectations, frequencies may be reduced.

Confirmation, performance and adaptive management monitoring will continue to be important for making decisions about ongoing site activities during the post-closure stage. Monitoring data will be used to identify what variances from predictions are occurring and whether such variances require action to eliminate or minimize effects on the environment. The data will also be used to understand the extended concentration pathways (ECPs) post-2100 for the post-closure phase. The role of adaptive management monitoring may diminish as the post-closure stage progresses and the long-term performance of closure measures and activities becomes more certain.

Table G-2 summarizes expected monitoring requirements for the post-closure stage, including environmental components that must be monitored along with the type, location and frequency of monitoring. Specific types of monitoring may be removed, provided there is a strong rationale describing why that component is not relevant to a specific site or operation. The environmental assessment process and subsequent regulatory processes might identify project-specific monitoring requirements that are not identified in table G-2. Also, the monitoring frequencies may be increased for closure activities that have less certainty about their expected performance.

3.1. Temporary and interim facilities

All temporary and interim facilities that will be associated with the construction of the mine waste management facility must be described. Temporary facilities are those that are established to facilitate construction activities only, for example coffer dams or temporary diversions. Interim facilities are those that are established for the duration of a single stage of a project, for example an interim spillway on stage 1 of a tailings dam. Provide designs for all temporary and interim facilities. If designs are provided in other documents, then references to those documents should be provided in the construction plan.

Identify design criteria for temporary and interim facilities and provide rationales for selection of the criteria. Design criteria should demonstrate appropriate management of risks during construction periods for temporary facilities and during expected lifespan for interim facilities. If the project will include a series of interim facilities, the selection of the design criteria must consider the combined lifespan of those facilities.

The minimum standards for flood routing for all temporary water conveyance and containment facilities are:

- conveyance of peak flows for design events with durations consistent with times of concentration for the contributing watersheds, or
- storage of volumes from the design events.

More stringent standards will often be required and strong rationale must be provided for applying these minimum standards.

Table G- 2 Minimum post-closure monitoring

TABLE G-2 MINIMUM POST-CLOSURE MONITORING				
ENVIRONMENTAL COMPONENT	TYPE OF MONITORING	LOCATIONS	FREQUENCY[2]	PURPOSES
Surface water	Water quality and flow	Reference	Quarterly	• Confirm reference conditions. • Understand project performance. • Interpretation of contaminant loading. • Water and load balance development and refinement. • Identify environmental effects or trends. • Adaptive management response.
		Internal (e.g., pits and ponds)	Quarterly	
		Discharge and seepage	Quarterly	
		Receiving	Quarterly	
Groundwater	Water quality and water level	Reference	Quarterly, or annual if seasonally stable	• Confirm reference conditions. • Understand project performance. • Interpretation of contaminant loading. • Water and load balance development and refinement. • Identify environmental effects or trends. • Adaptive management response.
		Internal (i.e., porewater)	Quarterly, or annual if seasonally stable	
		On-site	Quarterly, or annual if seasonally stable	
		Downgradient	Quarterly, or annual if seasonally stable	
Aquatic ecosystem[3]	Benthic and periphyton	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Exposed	Every three years	
	Sediment quality.	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	Every three years	
	Fish usage	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	Every three years	
	Contaminants in fish[4]	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Identify environmental effects or trends.
		Receiving	Every three years	
Air		Reference	Usually not required	• Confirm reference conditions. • Understand project performance.
		Upwind	Usually not required	

[2] If post-closure includes active water management, monitoring frequencies and program will be similar to active closure monitoring, described in Table G-1
[3] More frequent early post-closure monitoring of the aquatic ecosystem may be required for projects that rely on passive or semi-passive water treatment.
[4] Frequencies for monitoring of contaminant levels in fish and vegetation do not apply for uranium mining.

Table G-2 Minimum Post-Closure Monitoring				
Environmental Component	**Type of Monitoring**	**Locations**	**Frequency[2]**	**Purposes**
	Air quality (dust, specific contaminants of concern, criteria air contaminants)	Downwind	Usually not required	• Interpretation of contaminant loading and dust transport. • Adaptive management response. • Identify environmental effects or trends.
Meteorology	Temperature, precipitation, wind speed, wind direction, solar radiation, evaporation, snow accumulation	On site, within watershed.	Usually not required	• Understand ongoing climate conditions and trends. • Water management planning. • Water balance development and refinement.
Wildlife	Waterfowl use	Open water areas that contain mine affected water	Spring, summer, fall for duration sufficient to develop understanding of post-closure use patterns	• Adaptive management response. • Confirm environmental performance.
	Wildlife use	Mine site area and mine waste areas	Ongoing incidental observations	• Adaptive management response. • Confirm environmental performance.
	Contaminants in wildlife	Reference	Not usually required except as adaptive response	• Confirm reference conditions. • Confirm environmental performance. • Adaptive management response. • Identify environmental effects or trends.
		Tailings vicinity	Not usually required except as adaptive response	
Vegetation	Contaminants in vegetation[3]	Reference	Every three years	• Confirm reference conditions. • Confirm environmental performance. • Adaptive management response. • Identify environmental effects or trends.
		Waste covers	Annual to confirm that uptake is not occurring and every three years thereafter	
		Mine affected areas	Annual until reductions in contaminant concentrations in affected areas are demonstrated, and every three years thereafter for duration suitable to confirm acceptable uptake conditions	
Terrestrial	Permafrost conditions (subsurface temperature monitoring, visual inspections)	On site and mine affected areas	Every three years, or as an adaptive response	• Monitor stability and integrity of site and remaining infrastructure. • Adaptive management response. • Confirm environmental performance.
	Geohazards (landslides, slope failures, fluvial, permafrost, seismic)	On site and mine affected areas	Every three years, or as an adaptive response	• Monitor stability and integrity of site and adjacent areas. • Adaptive management response.

4. Monitoring quality assurance and quality control

The monitoring program must include a quality assurance/quality control program (QA/QC) that assures and verifies the monitoring results. The QA/QC program should address all components of the monitoring program from sample collection through to lab analysis and reporting.

5. Reporting of monitoring results

The monitoring plan must describe how and when results will be reported, including at least monthly and annual reports during the operational period.

- Monitoring results must be compiled and reported on a monthly basis during operations and active closure and quarterly during post-closure. When compiling these results, any abnormalities or unexpected conditions should be noted and, if necessary, addressed. Results must be provided for every proposed monitoring event, including rationale if no samples were collected or no monitoring conducted.
- An annual report must provide a summary of monitoring results and interpretation of results including any changes and trends. It must also include any recommendations for changes to the monitoring program.
- Reporting must included observed changes in climate conditions, updates to projections, and any adaptive management measures undertaken to address climate related impacts to operational and closure activities.
- Reporting must also include observations, or revised projections, require changes to previously conducted risk assessments, or if event thresholds for adaptation pathways have been passed or are likely to be passed during the life of the project.

Reporting of monitoring results during the post-closure stage can initially be reduced to a pattern of quarterly and annual reports. As monitoring frequencies fall after verification of suitable, stable environmental conditions, reporting frequency may be reduced to once per year.