DE-LICENSING OF OIL SANDS TAILINGS DAMS

Technical Guidance Document

OIL SANDS TAILINGS DAM COMMITTEE

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Acknowledgments

This document was written as a cooperative effort between the oil sands operating companies, the Alberta regulators and the engineering consultants involved in oil sands tailings dams with the intent of providing technical guidance for de-licensing of these facilities.

Committee Co-Chair and Project Manager:
Angela Küpper, AMEC, now BGC Engineering Inc.

Committee Co-Chair:
Barry Hurndall, BJH Engineering

Technical Reviewers:
Norbert Morgenstern, University of Alberta
John Sobkowicz, Thurber Engineering Ltd.

Members:
Walday Abeda, Canadian Natural Resources Ltd.
Gary Baldwin, Shell Canada Energy
Bob Cameron, Syncrude Canada Ltd.
Norm Eenkooren, Suncor Energy
Chris Grapel, EBA[3]
Scott Martens, Klohn Crippen Berger, now Shell Canada Energy
Gord McKenna, BGC Engineering Inc.
Yetim Mihiretu, Government of Alberta, Alberta Energy Regulator (AER)
Wayne Mimura, Syncrude Canada Ltd.
Kate Parsons, Government of Alberta, Alberta Energy Regulator (AER)
Santiago Paz, Gov. of Alberta, Environment & Sustainable Resource Development (AESRD)[1]
Tim Peterson, Norwest Corporation
Andy Small, AMEC[2]
Steve Tan, Total E & P
Karyn Wog, Epcor[3] formerly with Alberta Environment during this project
Shahram Yazdanpanah, Imperial Oil Resources

Review comments on the draft document by Javid Iqbal of the Government of Alberta, Environment & Sustainable Resource Development (AESRD) and by Andrea Larson and her team, of the Government of Alberta, Alberta Energy Regulator (AER) are also gratefully acknowledged.

[1] Canadian Dam Association (CDA) Director, Northern Alberta
[2] CDA Director, NB & CDA Mining Committee
[3] Former CDA Director, Northern Alberta, during this project

PREFACE

Following a number of dam failures in the 1970s the question was raised in Alberta whether sufficient attention was being paid to the regulation of dam safety. The Association of Professional Engineers and Geoscientists of Alberta (APEGA) took on accountability for finding a solution and I was invited to chair a Special Committee. The Special Committee was composed of a variety of stakeholders including dam owners, regulators and technical experts and recommended that regulatory requirements for dams be strengthened. This recommendation was accepted by Alberta Agriculture, which had the responsibility for tailings dams at that time under the Water Resources Act. These responsibilities subsequently moved to Alberta Environment and led to the establishment of the Dam Safety Office.

The Dam Safety Office quickly became a national leader and demonstrated its value to the oil sands industry when in 1975, it appointed the Tar Island Tailings Dyke Design Review Panel. Tar Island Dyke was the first tailings dam in the oil sands industry. The Canadian Dam Association (CDA) grew substantially out of the strength developed in Alberta, British Columbia and a few other jurisdictions. One of the most important publications from CDA are their recommended Dam Safety Guidelines, which form the basis for the approvals of dam safety not only in Alberta, but also many other jurisdictions in Canada and elsewhere. I have expressed the view that dam safety systems applied to the Alberta oil sands industry are the best in the world (Morgenstern, 2010).

A number of dams licensed by the regulator in accord with the Dam Safety Guidelines have now ended their active service life and others are close to it. For example, Tar Island Dyke is now transformed into a solid and trafficable landscape with advanced reclamation, after about forty years of service. However, if the license that governs the operation of the dam is not ultimately removed, it will require ongoing monitoring and reporting. Active care is not needed after closure design has been implemented and is in conflict with the desire of all stakeholders to remove obstacles to passive care and ultimate certification of the reclaimed landscape. Removing the license to operate as a dam does not imply any sense of imminent neglect. Instead, the dam is transformed into one of many landforms that have to be monitored and reclaimed to a level consistent with regulatory closure requirements.

Removal or breaching, are options open to consideration when de-licensing a water dam. However, these may be impossible or inappropriate for de-licensing a tailings dam since processes, such as erosion, may result in unacceptable consequences. Therefore, other than ensuring the dam does not have ponds large enough to qualify for licensing, there appeared to be no precedents to follow to de-license tailings dams in the oil sands, which are now moving toward more advanced stages of reclamation.

In response to this limitation, a group of interested stakeholders was convened to address this issue. Similar to the Special Committee established by APEGA, the group included owners, regulators and technical experts, operating in a consensual way, and supported by their organizations. This effort has been rewarded by the document presented here that provides a practical way forward to de-license oil sands tailings dams. We should be appreciative of the public service offered by all who contributed to this Technical Guidance Document.

Norbert R. Morgenstern, CM, AOE, FCA, FRSC, Ph.D., P.Eng.

Distinguished University Professor (Emeritus) of Civil & Environmental Engineering

University of Alberta

Reference:

Morgenstern, N.R., 2010. Improving the safety of mine waste impoundments. Tailings and Mine Waste '10, 14th International Conference on Tailings and Mine Waste, Vail, Colorado, p. 3-10, CRC Press.

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1.0 INTRODUCTION

1.1 Background

Oil sands open pit mines typically include mining pits, tailings dams, overburden structures (mine waste dumps) and various industrial plants. Once the use of these facilities is complete, the land will be reclaimed and returned to the Crown. Where practical, tailings facilities, mine waste dumps and mine pits will be closed and reclaimed progressively during operation to mitigate the overall impact of the mining activities on the environment.

Oil sands tailings dams (as defined in Appendix 1) are currently licensed or approved as dams under the Alberta Energy Regulator (AER) dam safety program. They are designed, built, monitored and operated in accordance with the Canadian Dam Association (CDA) Dam Safety Guidelines and various guidelines of the Mining Association of Canada (MAC).

Alberta's first oil sands tailings dams are now being closed and reclaimed. Once these structures no longer function as dams, retaining either fluid or mobile solids, it is necessary to de-license them as part of the closure process. There is currently limited guidance in the technical literature and in the regulations, in Alberta and elsewhere, on the requirements and the process to close, reclaim, and de-license a tailings dam.

This document presents a technical approach to take oil sands tailings dams to a stage where they can be de-licensed as dams and considered solid earthen structures.

Operators, regulators, and stakeholders are committed to the closure and final reclamation of oil sands mines and their associated tailings facilities. All activities related to design, construction, operation, and decommissioning have a direct influence on the success of closure and reclamation of tailings facilities, which is the ultimate goal of stakeholders. Oil sands tailings structures may function as dams for an extended period, during which the continuation of maintenance and surveillance is required. It is of importance to the oil sands industry and its regulator to develop a process by which tailings dams can be decommissioned, closed and de-licensed for final reclamation and certification.

1.2 Committee objectives

A working group, the Oil Sands Tailings Dam Committee ("Committee"), was formed in 2009 to outline a process whereby tailings dams could be transitioned to "solid earthen structures" (tailings and overburden piles) and de-licensed as dams. The focus of the Committee was to define the conditions that must be satisfied for a new solid earthen structure to no longer be considered a dam.

The Committee was formed as a collaborative initiative among Alberta regulatory agencies that have jurisdiction over oil sands tailings dams, oil sands operating companies with active and/or planned tailings dams, and the engineering design consultants primarily involved in oil sands tailings dam design. The Committee design was strategic to obtain input in the process by parties involved in the design, operation and regulation of oil sands tailings retaining structures. The Committee's representatives were senior professionals with experience in oil sands, and tailings dams in particular. They convened from 2009 through 2013.

The approach presented in this document is intended for the oil sands tailings dams of Alberta, yet it contains elements that may be applicable to other jurisdictions and types of tailings dams with due consideration of their specific regulatory situation and any special conditions. The collaborative approach adopted here by owners, regulators and consultants is also applicable to other places and industries.

1.3 Document scope

This document focuses on the de-licensing of oil sands tailings dams in Alberta as part of the process of transitioning these structures toward final closure and reclamation certification. This document deals specifically with the structural integrity aspects of the facility – geotechnical and hydrotechnical stability – for the final stages of its life cycle. Discussion of the environmental aspects is outside the scope of this document, yet remain a consideration when closing tailings dams.

There are other documents and guidelines related to tailings dams in general. For example:

- The Mining Association of Canada (MAC) (2011) *Guide to the Management of Tailings Facilities* outlines management practices over the life cycle of a tailings facility: from site selection to design, construction, operation, decommissioning and closure.

- The Canadian Dam Association (CDA) *Dam Safety Guidelines* provide guidance for the design and operation of dams in general, including tailings dams.
- The CDA is currently working on a bulletin specifically on tailings dams.
- The International Commission on Large Dams (ICOLD) has a series of technical bulletins on tailings dams.

Traditional water dams found on oil sands mine sites, and dams from other mining industries (e.g., coal, hard-rock mining, etc.), are not within the scope of this document.

It should be noted that this document is intended for a technical audience with experience in open-pit oil sands mining and the related issues of managing oil sands tailings.

1.4 Regulatory oversight of oil sands in Alberta

In Alberta, oil sands tailings dams are regulated from their early stages of planning through design, construction and operation, to cessation of operations, decommissioning, reclamation and final certification as a landform. The Alberta Energy Regulator (AER, formerly ERCB) is currently the regulator for these structures. The regulatory oversight of oil sands in Alberta was being re-organized as this document was being finalized therefore there could be changes from what is described here.

The approval/license for tailings dams is issued in Alberta under the Water Act. In addition to having jurisdiction over dam safety, the role of the regulator includes authorizing the placement of the tailings facility on a mine site, aiming at minimizing ore sterilization in the footprint of the impoundment and the regulation of production and deposition of tailings in the impoundment area.

Both AESRD and AER also regulate other mine waste structures such as overburden dumps and similar facilities that do not impound fluids.

Applicable legislation includes:

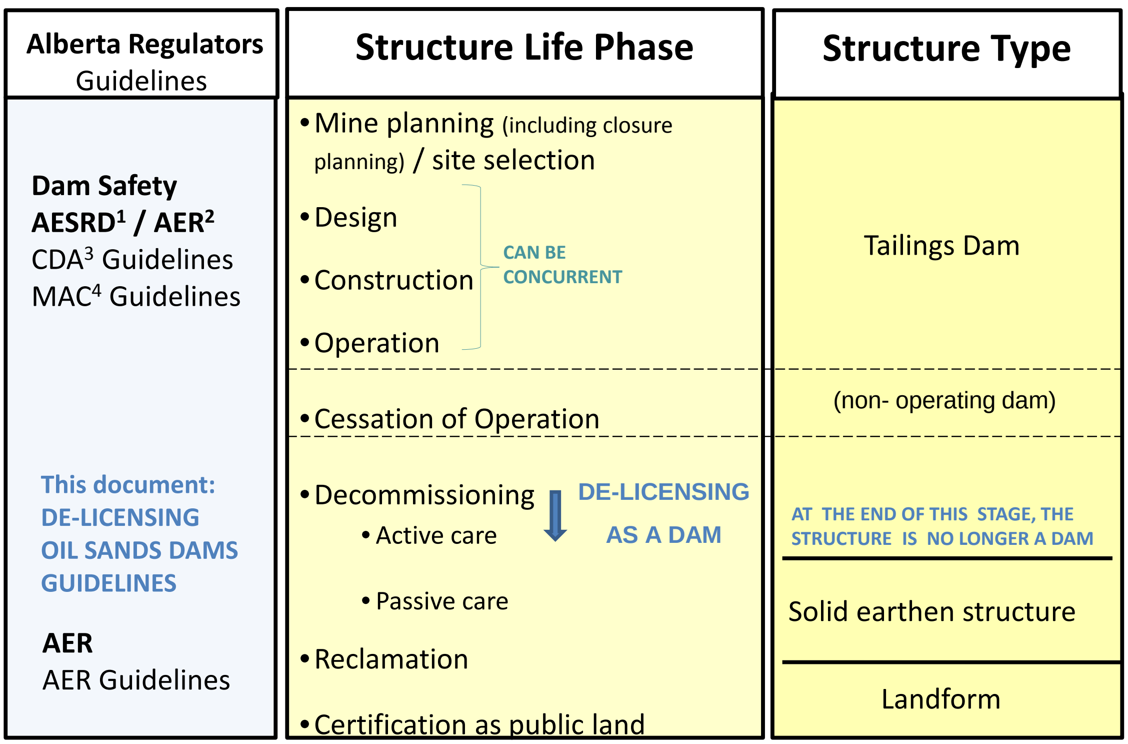
- *Oil Sands Conservation Act*
- *Oil Sands Conservation Rules*
- *Water Act and Water (Ministerial) Regulation*
- *Environmental Protection and Enhancement Act*
- *Public Lands Act.*

The AER is the regulator for oil sands tailings facilities as they move toward becoming a landform during the decommissioning and reclamation process. It is the AER that ultimately issues the Reclamation Certificate to the operator on behalf of the Government of Alberta. The Reclamation Certificate means that the land has been transformed into a landform in a suitable state to return to the Crown.

1.5 Stages of a tailings facility and adopted terminology

1.5.1 Phases of the life of an oil sands tailings facility

The phases of the life of an oil sands tailings facility are summarized in Figure 1.1. The adopted terminology is described in Section 1.5.2. This figure also indicates the type of structure for the various life phases and the guidelies for each of the stages.



[1] Alberta Environment and Sustainable Resource Development
[2] Alberta Energy Regular
[3] Canadian Dam Association
[4] Mining Association of Canada

Figure 1.1 – Phases of the life of an oil sands tailings facility

Typically, the initial stages of development for a tailings facility include mine planning and site selection, followed by design, construction and operation of the tailings dam, including monitoring, surveillance and maintenance. Mine planning should include a high level closure plan to help achieve cost effective closure of the mine. Similarly, decommissioning and de-licensing need to be a consideration in the design of tailings facilities to support cost effective decommissioning and progressive reclamation. The nature of these facilities is such that design, and especially construction and operation, tend to occur concurrently.

1.5.2 Adopted terminology

There is a significant variability in the terminology used to describe the various stages of the life cycle of a tailings facility. For this reason, the terminology that has been adopted for this document is described in this section.

Oil sand tailings dam or dyke: refers to a fluid retaining structure that exists at oil sands mining sites for the purpose of storing water and tailings resulting from the bitumen extraction process. The dam or dyke is understood to be an approved/licensed structure under the *Water Act*. The definition of dam is further discussed in Section 1.5.3.

Operating/active tailings dam: receives liquids and/or tailings, and typically has fluid reclaiming facilities. The dam may still be under construction and not yet built to final design height. An operating/active tailings dam requires ongoing surveillance and monitoring and regular reporting of its structural and operational condition. This includes submission of yearly performance reports and scheduled independent dam safety reviews to the regulator.

After the impoundment final capacity is achieved, the dam can continue in operation as a settling basin and/or a recycle water reservoir, or it can become non-operational. In either case, the structure remains a dam, containing fluid and potentially mobile tailings deposits, and thus continues to require regular reporting of its structural and operational condition to the regulator.

Non-operating/inactive dam: a dam that is no longer receiving tailings or fluids other than precipitation and run-off. It may still have water reclaiming facilities to control its water level, and continues to require active surveillance and monitoring and regular reporting to the Dam Safety regulator, including submission of independent dam safety reviews.

During all the stages when the structure is considered a dam, it should be planned, designed, built, operated and managed according to the CDA and MAC Guidelines.

Decommissioning: a non-operating dam that is to be reclaimed goes through a transitional stage when various measures are implemented to convert the tailings dam and deposit area (tailings facility) into a solid mine waste structure ("solid earthen structure"). These measures may include removal of the impounded fluid, removal of soft and/or mobile tailings, removal of operational structures, breach of the containment structure, construction of outlet channels and other closure measures. The plan and design of the measures need to be submitted to and authorized by the regulator for implementation. The decommissioning period will include active care, when it is demonstrated that the solid earthen structure performs as intended and can be de-licensed as a dam, to a passive care stage.

De-licensing process: During the de-licensing process, a tailings facility transitions from a licensed dam to a de-licensed structure. The decommissioning and the initial period of active care are part of the de-licensing process. The process includes preparation of a design plan for the measures to be implemented for the transition, submittal of this design to the regulator, authorization from the regulator to install the measures and approval by the regulator, at which point the structure is de-licensed as a dam and becomes a solid earthen structure. During this process, it is necessary to demonstrate that the transition of a tailings facility into a solid earthen structure has achieved the objectives of the de-licensing process, that the tailings dam no longer meets the definition of a dam, and that it will not revert to a dam in the future.

Monitoring of the structure for some period may be required to help demonstrate that the structure now meets all the requirements for de-licensing. When the facility is de-licensed as a dam, regular reporting of the facility's structural and operational condition to the Dam Safety regulator is no longer required. After the structures go through final reclamation, they constitute landforms. These solid earthen facilities will cease to be the subject of dam safety regulations.

Monitoring: during the decommissioning stage the structure is monitored by the mining operator. This stage includes two periods:

> *Active Care*: the period when monitoring and possibly minor active intervention is required to achieve a final sustainable stable form. De-licensing of the dam occurs during this period, as active care of the solid earthen structure may still be required for a period.

Passive Care: the period following active care, during which the performance of the solid earthen structure is monitored to ensure its compliance with the closure objectives. This period has no time limit but can be defined as being necessary until the structure is demonstrated to be physically, chemically, and ecologically stable, having a performance, and a residual risk level compatible with the surrounding natural areas.

Reclamation (or final reclamation): this is the process a solid earthen structure or a landform must go through to qualify for certification as a landform and receive a Reclamation Certificate.

Certification of the landform: landforms are required to meet all provincial and federal closure and reclamation criteria to obtain a Reclamation Certificate issued by the regulator. At this point, the landform is no longer under the jurisdiction of the mine operator and it is transferred back to the Crown as public land (relinquishment).

1.5.3 Modified definition of dam

A **dam** is defined in the *Water Act*, Water (Ministerial) Regulation, Part 6, and in the 2007 Canadian Dam Association (CDA) Dam Safety Guidelines, as a barrier constructed for the retention of water, water containing any other substance, fluid waste, or tailings, provided the barrier is capable of impounding at least 30,000 m^3 of liquid and is at least 2.5 m high. The term dam includes appurtenances and systems incidental to, necessary for, or connected with the barrier. In the context of earth dams, the barrier may be constructed either by placing fill or by excavating native ground such that a pillar of in situ material is formed.

CDA (2007) proposes that this definition be expanded to include smaller dams if the consequences of dam operation or failure are considered unacceptable. Fundamentally, the formal definition of a dam accounts for consequence of failure. The height of the barrier and the volume of fluid impounded are directly related to potential consequence of failure. Following the same fundamentals, the width of the structure could also be taken into account in the definition of a dam. It is possible to envisage a situation where the width of the barrier retaining fluid is so large that the barrier does not constitute a dam.

Therefore, similar to CDA (2007), expanding the definition of a dam to include smaller dams if the consequences of failure are likely to be unacceptable, this document proposes a limitation of the definition of a dam to exclude cases where the width of the barrier is so large that the residual risks associated with the barrier are negligible and a potential breach of the barrier, exposing contents, is not practically possible now or in the long term. This proposed limitation of the definition of a dam respects the fundamental principle of the current formal definition in its consideration of the potential consequences of failure.

1.6 Document overview

This document outlines a framework for oil sands mine operators (the "operator") to prepare a submission, for consideration by the regulator, for the transition of an oil sands tailings dam from a licensed dam to a solid earthen structure that is no longer licensed as a dam. This de-licensing of an oil sands tailings dam is a critical step in the reclamation and closure process for oil sands tailings dams and their tailings deposit areas in Alberta.

The proposed de-licensing framework is founded on a performance and risk-based approach, outlining a process of identifying and implementing measures that would be required for a given oil sands tailings dam to transition to the status of a solid earthen structure. After a proposed design has been developed for converting the dam and tailings deposit area into a solid earthen structure, a detailed risk assessment is conducted on this design. The risk assessment involves:

- Identifying the hazards and potential failure modes
- Analyzing the hazards
- Assessing the consequences
- Evaluating the probabilities of occurrence
- Characterizing the overall acceptability of the residual risk
- Re-designing for further reduction of the residual risk, if required.

This design would then be implemented along with a monitoring program to determine the performance and integrity of the structure. Monitoring during and after implementation of the proposed design may indicate that additional measures might be required, such that the structure meets an acceptable risk level for de-licensing, and eventually final reclamation. The objective is for the operator to demonstrate to the regulator that the residual risk for the structure has been reduced to a level compatible with that of the natural analogues.

Completion of the submission process outlined in this document does not guarantee automatic removal of regulatory requirements or oversight on an existing oil sands tailings dam. Review of each submission and consideration for de-licensing of a tailings dam is the sole purview of the regulator. As such, the regulator may have additional submission requirements for each specific structure that the operator is seeking to have de-licensed as a dam.

2.0 BACKGROUND – OIL SANDS TAILINGS DAMS

2.1 Oil sands overview

In Alberta, the occurrence of bituminous sand, commonly known as oil sands, has led to the development of an industry that has grown significantly since the 1960s. Oil sand is a sandy deposit, with varying fines content, that has bitumen and water in the pores of the particulate structure. The bitumen is too viscous to be pumped using traditional methods and is recovered from the oil sands using open-pit mining or in-situ treatment methods.

As of 2012, the largest bitumen deposits are found in the Athabasca region of Northeastern Alberta, where extensive mining operations are underway. Other known bitumen deposits in Canada are found in the Peace River and Cold Lake regions of Alberta and in the province of Saskatchewan. They are also found in Venezuela, the United States, Russia and the Congo.

2.2 Physical setting of the Athabasca oil sands region

A brief description of the physical setting of the Athabasca oil sands area is included here to provide context to some of the issues associated with earthen structures in the region that affect the performance of tailings dams, the transition of these structures into solid earthen facilities and eventually to landforms. These issues affect these structures at all stages of their life cycle.

The oil sands regional climate is classified as hemiboreal or between temperate and subarctic zones. The mean annual precipitation is 437 mm (1944-2009, Fort McMurray Airport) yet potential evapotranspiration exceeds precipitation on a monthly basis from April through September as well as on an annual basis based on long-term average precipitation values. The hydrology of the area, therefore, tends to be favourable for the closure and reclamation of tailings facilities.

The topography of the Athabasca oil sands mining area is subdued with relatively flat to undulating relief. The drainage (rivers and most creeks) is incised. The natural valley slopes commonly present slope instabilities associated with the various weak glaciated strata that form the stratigraphy of the area.

The geology of this region of Northern Alberta comprises mainly recent glacial deposits, overlying weak Cretaceous Clearwater Formation clay shales, which are underlain by Cretaceous McMurray Formation oil sands, interbedded with clay shale (see Appendix 2). In some areas, the Cretaceous shales are not present, having been partially or wholly eroded during glaciation. Interbedded limestone and shale of the Devonian Waterways Formation lie beneath the mineable resource and are persistent throughout the region.

The weak clay shales in the McMurray Formation, and particularly the Clearwater Formation, often require very flat slope angles (as flat as 20 or 25H:1V) on tailings dams founded on these materials. However, these extensive shale layers have very low permeability and significantly reduce seepage of fluids from tailings impoundments into the foundation materials. Some water-bearing sands are present in the McMurray Formation, particularly near its base. In addition to this, the presence of weak materials at the base of the McMurray Formation (basal clays and paleosol) may also result in flat slopes for structures built on these materials.

2.3 Tailings deposits

Several types of tailings deposits result from the processing of oil sands from open-pit mining and the selected tailings management methodology. Oil sands tailings streams may include fluid fine tailings (FFT), mature fine tailings (MFT), tailings sand (TS), composite tailings or consolidated tailings (CT), non-segregating tailings (NST), “densified” cycloned tailings (DT), centrifuge tailings, froth treatment tailings as well as other possible tailings types. These tailings materials may form deposits that range from dense to loose sands to semi-fluid clayey materials. The shear strength of a tailings deposit varies widely depending on the nature of the material, the density of the deposit, the degree of consolidation and other factors. As processing and dewatering technologies continue to evolve, the composition and physical properties of the tailings discharged in tailings facilities may change and could influence the mitigating measures required to modify a structure for de-licensing a dam.

2.4 Tailings dams characteristics

Two primary types of tailings impoundments are used in oil sands mining: external tailings facilities and in-pit tailings facilities.

External tailings

External tailings facilities are located on natural ground where the poorest bitumen reserves are present and are typically used to store tailings from the first several years of mining a new lease, until sufficient space has been opened within the mine pit. At this point, a dyke can be constructed across the pit, so that mining can continue on one side while tailings are discharged into the mined-out area on the other side. Due to the flat topography, most external tailings facilities are constructed in a ring shape, with tailings stored in the interior pond.

In-pit tailings facilities

In-pit dykes are constructed to sub-divide the mined out pit into cells, which are created sequentially as mining progresses. Most cells will hold solid tailings, though at closure one or more cells may hold fluid as an End-Pit Lake. Once mining and backfilling of the cells is complete, most in-pit dykes cease to be a retention structure as material is placed on each side of the dyke. Water in the End-Pit Lakes and some potentially mobile solid tailings may remain in some of the cells, retained by natural pit walls and/or in-pit dykes.

Other aspects of oil sands tailings dams

Oil sands tailings dams are constructed using a variety of techniques, from conventional compacted fill methods to hydraulically-placed tailings using sequential-raising methods (upstream, downstream, centreline and modified centreline methods) to incorporation of in-situ pillars or a combination of all or some of these methods. Oil sands tailings dams are built using compacted fill from overburden and interburden materials (e.g., lean oil sand, clay shale, till), tailings sand, coke or a combination of these materials. They are often built gradually as dam operation proceeds. Their service life typically spans from a few years to several decades.

The permeability of overburden and interburden materials is typically low due to the presence of fines and/or some trace bitumen in the void spaces, whereas the permeability of the tailings sand may be medium to high, depending on fines content.

The flat slopes required due to weak foundation materials, combined with the large production of the oil sands mines and the use of large mining equipment for construction, lead to the large size of most oil sands tailings dams. Several dams in the oil sands region are more than 100 m high, with the majority of them being higher than 50 m. Crest widths are typically 30 to 50 m but can be up to several hundred metres including the beaches that are used for some dam types. Crest lengths range from several hundred metres for in-pit dykes to more than ten kilometres for some external tailings facilities. The base widths of these dams often approach or exceed 1000 m. It is important to take into account the generally positive benefit of the large cross sections of these structures when assessing their potential failure modes and the mitigating measures required to de-license these dams.

The relatively flat to undulating topography of the Athabasca oil sands area results in the tailings facilities either having a relatively small contributing watershed or being a ring dyke, where the watershed is only the facility itself. This fact, combined with the relatively dry climate of the area, is also a significant positive aspect when considering the risks associated with the various phases of the life of the facility.

Operation and performance

Oil sands dams are operated under the precepts of the *CDA Dam Safety Guidelines*, as required by the regulator. The MAC *Guide to the Management of Tailings Facilities* is also generally followed by the oil sands mine operators. Surveillance records covering all or most of the service life of the structures are generally available.

3.0 DAM DE-LICENSING PROCESS

3.1 Framework for de-licensing

The proposed de-licensing process involves transitioning a structure from a licensed tailings dam to a solid earthen structure followed by an application for formal de-licensing when all requirements are met.

During the de-licensing process, it will be necessary to monitor the structure for some period to demonstrate that the structure now meets all the requirements for de-licensing. If monitoring of the structure indicates the need for additional mitigation measures, these measures would be implemented until it can be demonstrated that an acceptable performance of the solid earthen structure has been achieved. At this point, a submission to the regulator may be prepared to formally de-license the structure.

3.2 Objectives

The objectives for the closure of an inactive oil sands tailings facility, and its transformation into a solid earthen structure that qualifies for de-licensing as a dam, are:

1. The structure should be modified in a manner that:

    a. It no longer meets the definition of a dam; and

    b. The probability of the facility ever reverting to a configuration that meets the definition of a dam is extremely low.

2. The resulting structure is considered to have a physical performance that, as a minimum, can be managed as a solid earthen structure (or a conventional waste dump) but that ideally is compatible with the performance of the natural landforms in the region.

It is noted that the natural areas in the oil sands region, as in all other areas of the planet, undergo a geomorphic process of landscape evolution. As part of this natural process, slope instabilities, surface erosion, wave and river erosion, groundwater level fluctuation, fires, etc., occur in the region.

The objectives listed above are the objectives that need to be met for a structure to qualify for de-licensing as a dam. Final closure of a solid earthen structure, so that it eventually qualifies for a Reclamation Certificate, would meet additional objectives (including all environmental aspects), however, these objectives are not within the scope of this document.

3.3 Integrity assurance

Risk is defined as the probability of failure multiplied by the consequence of failure. It is the expectation of society that all dams pose acceptably low risk to people, the environment, and to cultural and economic values. During operations, the performance of each dam is monitored (to a degree consistent with the consequence-of-failure classification of the dam), and remedial measures are invoked as needed to maintain an acceptably low risk of failure. This applies to both operating and non-operating dams, since they still maintain a dam status.

When a tailings dam is converted to a solid earthen structure for de-licensing as a dam, the risk is further mitigated by reducing both the consequences and the probability of failure. The closure measures designed and implemented to convert the tailings facility into a solid earthen structure need to further reduce the risk such that it is compatible with the risk level of the surrounding environment. During the post-closure period, some level of monitoring is required, providing an opportunity to demonstrate the structure's integrity and performance.

3.4 Scenarios

The current configuration of oil sands tailings dams and the various closure landscapes being considered by the oil sands industry could lead to the following three scenarios relative to the de-licensing of oil sands dams:

Scenario 1 – No significant surface water or fluids in the solid earthen structure

This scenario occurs when all water, fluid tailings and potentially mobile solids are removed from the former tailings facility, which then transitions to a typical mine waste dump or solid earthen structure. In this case, the final configuration of the solid earthen structure would be such that there will be no future accumulation of water in the facility. This scenario could be developed, for example, by removing all fluids and potentially mobile solids and by completely infilling a tailings facility to achieve a domed shape that will shed water even if some settlement occurs in the future. Scenario 1 poses the least challenge for de-licensing the structure as a dam.

Scenario 2 - Minor surface water in the solid earthen structure

In this case, the former tailings facility may have a small pond on the surface, designed as part of the closure landscape, to provide wildlife habitat and run-off controls. Such a pond would mimic naturally occurring water bodies in the region and would be designed with measures to prevent excessive water accumulation. The pond volume should be less than the minimum volume in the definition of a dam or the pond location should be sufficiently far from an area of lower topography that the width of intervening material is so extensive that it does not constitute a dam (see Section 1.5.3). An example of this scenario is a ring dyke tailings facility, common in the oil sands area, that has all fluid and most soft tailings removed and is breached at one location where an outlet is implemented. The original, typically very wide dam structure would remain but it would not impound any significant amount of fluid in the present or the future, although a minor pond or wetlands area might be formed in its interior. An outlet channel that is sustainable in the long term is a critical element of this scenario. An example of this scenario is discussed in Section 4.0 to help present the proposed risk assessment approach.

Scenario 3 - Significant surface water or mobile solids in End-Pit containment

Some closure landscapes of mined-out pits are envisioned where larger water bodies or deposits of potentially mobile solids are contained by barriers of constructed and/or in-situ materials. If the width of these barriers is sufficiently large that there is negligible risk of release, for all reasonably foreseeable present and future sets of circumstances that may act to modify the barrier, the barrier would not be deemed to be a dam as per Section 1.5.3. The barrier dimensions needed to achieve these conditions would vary based on the nature of the contained materials, the properties of the barrier, and the potential external conditions that may affect the barrier. Current in-pit dams may need to be modified to achieve the required conditions to qualify for de-licensing. It would be the operator’s responsibility to demonstrate that a suitably low level of residual risk is achieved by the structure to be de-licensed. An example of this scenario would be the end pit lakes that are being considered in some closure plans. A guide document to planning and design of end pit lakes was published by the Cumulative Environmental Management Association (CEMA) in 2012.

3.5 Approach for de-licensing a dam

The proposed approach for the de-licensing of an oil sands tailings dam is summarized in Figure 3.1.

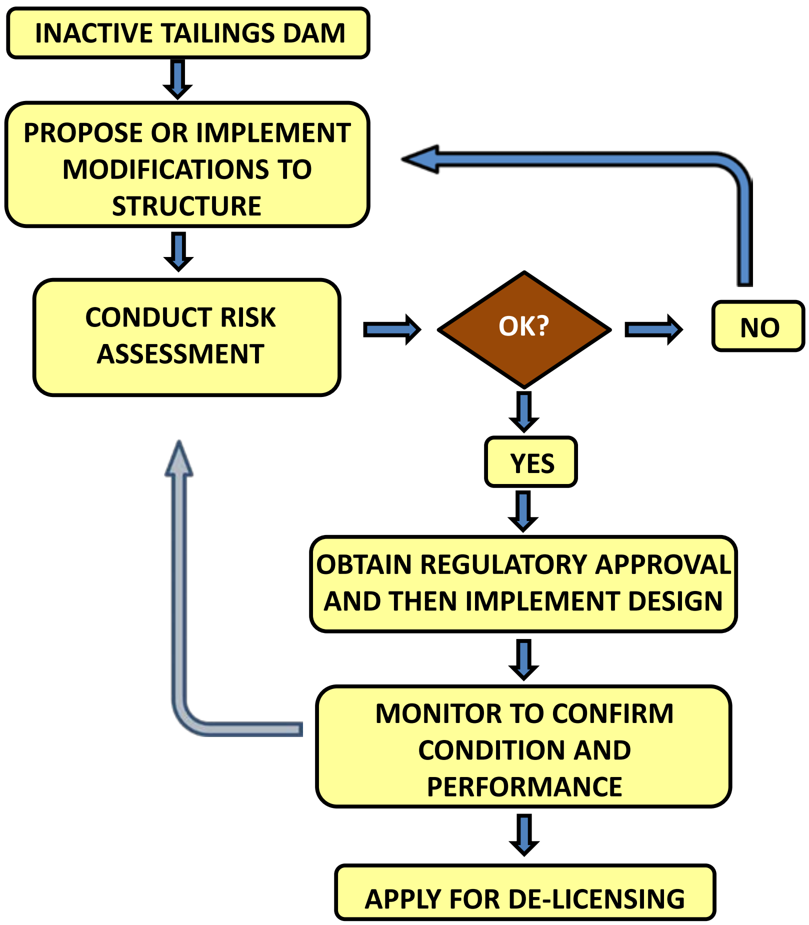


Figure 3.1 – Summary of proposed approach for de-licensing

The proposed approach for the de-licensing of an oil sands tailings dam involves the following steps:

1. Cease operation and turn the tailings dam into a non-operating (inactive) facility.
2. Propose measures to modify the structure, so that it meets the objectives in Section 3.2. The actual measures required will vary by structure and should be considered and assessed using a Failure Modes and Effects Analysis (FMEA) or a similar approach.

3. Conduct a risk assessment to determine whether the proposed measures would lead to a residual risk that is appropriately low (i.e., compatible with the risks of the natural areas in the region for all reasonably foreseeable circumstances, including extreme weather events, seismic events, slope instability, channel or outlet instability, and erosion). If the residual risk is not acceptable, identify additional measures to reduce the risk further. Repeat the risk assessment until the proposed measures result in an acceptable risk level.
4. After obtaining regulatory approval for making changes to the structure, implement measures identified in steps two and three and monitor the performance of the modified structure during implementation and then over a sufficiently long period to confirm that the performance target was achieved and the risk level is acceptable. The structure eventually should have a performance compatible with the performance of the natural areas in the region for all reasonably foreseeable circumstances.
5. When it can be demonstrated that the modified structure meets the de-licensing objectives, apply to the regulator to de-license the structure as a dam.

After de-licensing the structure, additional measures are required to complete the closure process, including:

a. Implement further reclamation activities as necessary to meet the conditions for final closure and Reclamation Certification.
b. Monitor the performance of the reclaimed facility over a sufficient period to confirm that the performance target was achieved with no active care.
c. Apply to the regulator to receive a Reclamation Certificate for the structure and return its responsibility to the Crown.

4.0 RISK ASSESSMENT FOR DE-LICENSING

4.1 Introduction to risk assessment approach

It is common in modern practice in the dam industry to incorporate risk-based approaches for design, operations and regulation. Extending the practice to dam de-licensing (and later closure and reclamation) is a logical step, and it is the approach adopted in this document. A risk-based approach in this context is a systematic assessment to identify the sources and magnitude of risk within the system. The tailings facility (tailings dam and deposit area) is treated as a system, which is broken down into its individual components to determine the fundamental causes of risk. This structured approach looks at both the likelihood of failure of the components and the system as a whole as well as the consequences of a potential failure. The risk assessment must be undertaken by qualified and experienced professionals.

The proposed risk-based approach for de-licensing of oil sands tailings dams follows the steps described in Section 3.5 and summarized in Figure 3.1. It includes the following four components:

- ***Hazard identification and analyses***. During this stage, the potential hazards and conditions that could lead to inadequate performance relative to dam safety or failure are identified along with their contributions to vulnerabilities of the system and the potential risks. All potential failure modes associated with these hazards are identified and analyzed.

- ***Risk assessment.*** This component is used as a check that the proposed closure design for the tailings facility will or has already transitioned into a structure that meets the requirements for de-licensing. If the risk assessment shows that the residual risk is still unacceptably high for de-licensing, additional risk reduction measures are identified and implemented and the process is repeated.

- ***Risk reduction***. The structure is modified so that the incremental residual risk associated with its structural integrity is negligible (i.e. the residual risk is compatible with the risk level of similar events in the natural terrain). During the early post-closure stage, some level of monitoring will be required to be in place and maintenance would be done, if and as required. For the later post-closure and the reclamation certification stages, the incremental residual risk needs to be negligible with no maintenance.

- ***Risk communication***. There needs to be communication among the stakeholders involved in the process of de-licensing a dam relative to the residual risks associated with the solid earthen structure.

The four components of the risk-based approach are discussed in detail throughout this section. To facilitate this discussion, an example case was prepared to illustrate the de-licensing process. For the example, a typical oil sands ring dyke tailings dam was selected. It was considered that the example dam was to be de-licensed as a Scenario 2 solid earthen structure -- a structure that might have a minor pond or wetlands area in its interior as described in Section 3.4.

4.2 Hazard identification and potential failure modes

The external/internal hazards and the potential failure modes for tailings dams and for solid earthen structures are well understood, as are methods for assessing risk for particular structures and for developing measures to mitigate risk. Most of the hazards and many of the failure modes used for dams have direct application in assessing the failure risk for oil sands tailings facilities being de-licensed.

Potential failure modes can be analysed using a Failure Modes and Effects Analysis (FMEA). FMEA is a method of identifying and analyzing the component failures and their associated consequences. For a tailings dam or a solid earthen structure, a FMEA would incorporate a review of the system to identify the mechanisms through which the structure, its foundation, and any appurtenances could potentially fail under imposed loads or other external influences. For each structure, the process is site-specific, and relies on site data, design and construction aspects and information regarding the past behaviour of the structure, and it is calibrated by an understanding of the behaviour of similar structures.

Operators and the engineer-of-record are responsible for determining all the failure modes that may be specific to each structure. Failure modes could include:

- External slope failure
- Internal slope failure
- Piping failure / internal erosion

- Failure of drainage outlet slopes, leading to an increase in ponded water on the structure
- Consolidation of contents leading to settlement and a deeper existing pond or creation of a new pond
- Liquefaction failure
- Excessive erosion.

The hydrotechnical failure modes considered in de-licensing dams in the oil sands region relate to issues such as:

- Drainage outlet hydraulic stability
- Surface water erosion of slopes
- Overtopping.

All elements and conditions that could contribute to risk and vulnerabilities of the system need to be considered in the risk analysis.

For a complete risk analysis, all potential reasonable failure modes will need to be considered, at different locations along the structure. For example:

- Assessing the potential for large slope failures could require stability analyses at numerous cross sections, and in some cases additional analyses to assess potential three-dimensional effects on stability. An example is provided in Figure 4.1 that could be used for each critical cross-section, while maintaining a view of the overall tailings deposit area. Various event sizes should be assessed separately as the probabilities and consequences of events of different sizes will be different.

- A possible outlet failure is specific to the drainage plan, its design characteristics and the conditions at the drainage outlet area.

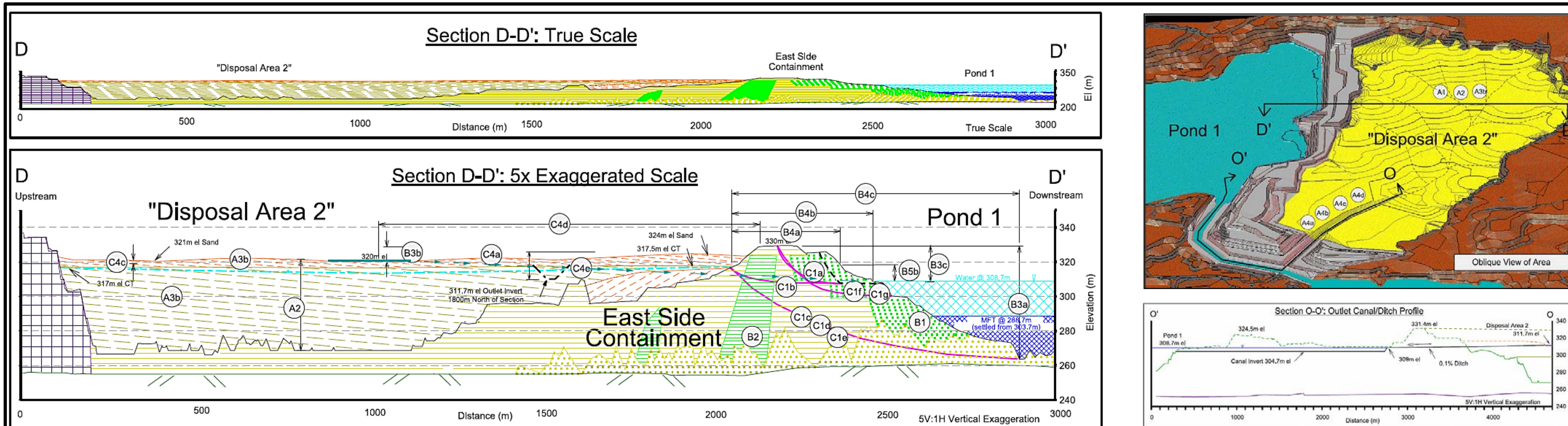


Table A - Fluid Pond or Potentially Mobile Solids Disposal Area Parameters at Closure:			
Area Parameters		**Typical Units**	**Typical Value**
A1: Surface Area of Pond/Disposal Area		hectares	
A2: Depth of Pond/Disposal Area (Min/Typ/Max)		meters	
A3: Type and Volume of Contained Tails*	A3a: fluids: water, mature fine tails, other	type, Mm3	
	A3b: potentially mobile (saturated) solids: composite tails, BBW sand, coke, centerfuge cake, other	type, Mm3	
A4: Pond/Disposal Area Outlet Parameters	A4a: bank height above outlet (max/min/typ)	meters	
	A4b: height from outlet to water table in potentially mobile solids	meters	
	A4c: outlet slope angle	% or degrees	
	A4d: outlet dimensions	depth x width x length	
	A4e: outlet construction material or in situ	type	

* Fluid and potentially mobile solids definitions are still being worked in detail and used here for study purposes only

Table B - Section Parameters at Closure for Fluid Pond or Potentially Mobile Solids Disposal Area:			
Section Parameters		**Typical Units**	**Typical Value**
B1: Type of Retaining Structure - State w ether structure is fluid of potentially mobile solids retaining	i) cell constructed sand	type	
	ii) overburden/ interburden fills		
	iii) in situ pillar		
	iv) combination of above		
B2: Height of Retaining Structure	B2a: above downstream structure toe	meters	
	B2b: above contained pond/disposal area's internal valley (bank height)	meters	
	B2c: to top of adjacent pond (if applicable)	meters	
B3: Horizontal Width from top of Pond /Water Table Within Potentially Mobile Solids to Structure Toe	B3a: to same elevation on downstream slope	meters	
	B3b: to top of adjacent pond (if applicable)	meters	
	B3c: to structure toe	meters	
B4: Height of Top of Pond /Water Table Within Potentially Mobile Solids	B4a: above topography	meters	
	B4b: above top of adjacent pond (if applicable)	meters	
B5: Potentially Mobile (Saturated) Solids Liquefied Flow Out Angle (if applicable)		% or degrees	

Table C - Section Failure Modes at Closure for Fluid Pond or Potentially Mobile Solids Disposal Area:			Risk Category Determination		
Failure Mode*	**Design Considerations****	**Technical Study**	**Consequence**	**Probability**	**Risk Category**
C1: Downstream Slope Instability for Section being Considered	C1a: local slope instability - no loss of contents	2013 Slope Stability Analyses Report Including Seismic Consideration, by Consultant A	A	4	Acceptable
	C1b: fall-down slope instability to edge of contents - no loss of contents		A	2	Acceptable
	C1c: fall-down slope instability - loss of contents < 500m x 500m		B	2	Acceptable
	C1d: fall-down slope instability - loss of contents < 1km x 1km		D	1	Acceptable
	C1e: fall-down slope instability - loss of contents > 1km x 1km		E	1	Further Review
	C1f: drawdown slope instability from 'realistic' lowering of adjacent pond		A	3	Acceptable
	C1g: drawdown slope instability from worst possible case lowering of adjacent pond		D	1	Acceptable
	C1h: long-term wave erosion impact (if applicable)	2012 Erosion Study	A	4	Acceptable
C2: Upstream Slope Instability for Section being Considered	C2a: local slope instability - no loss of contents	2013 Slope Stability Analyses Report Including Seismic Consideration, by Consultant A	A	4	Acceptable
	C2b: fall-down slope instability to edge of contents - no loss of contents		A	3	Acceptable
	C2c: fall-down slope instability - loss of contents < 500m x 500m		B	2	Acceptable
	C2d: fall-down slope instability - loss of contents < 1km x 1km		C	2	Acceptable
	C2e: fall-down slope instability - loss of contents > 1km x 1km		E	1	Further Review
	C2f: drawdown slope instability from 'realistic' lowering of contained pond		Not Applicable		
	C2g: drawdown slope instability from worst possible case lowering of contained pond		Not Applicable		
	C2h: long-term wave erosion impact (if applicable)	2012 Erosion Study	Not Applicable		
C3: Piping Failure/Internal Erosion Through Structure Leading to Loss of Contents on Section Considered	C3a: seepage/exit gradient through engineered fills	2013 Seepage Study Report, by Consultant C	B	2	Acceptable
	C3b: seepage/exit gradient through non-engineered fills		B	2	Acceptable
	C3c: seepage/exit gradient through in situ pillar		A	1	Acceptable
	C3d: seepage/exit gradient through foundation		Not Applicable		
C4: Outlet Failure for Section being Considered & for Oblique View	C4a: bank height above outlet	2013 Hydrology Study Report, by Consultant D	A	1	Acceptable
	C4b: minimum bank height as shown on oblique view above outlet vs hydrology design		A	1	Acceptable
	C4c: outlet ditch integrity/erodability vs hydrology design based on outlet slope(s)		A	1	Acceptable
	C4d: outlet spillway integrity/erodability vs hydrology design based on outlet slope(s)		Not Applicable		
	C4e: long-term wave erosion impact (if applicable)	2012 Erosion Study	A	2	Acceptable
C5: Excess Settlement /Ponding in Non-Fluid Disposal Area for Section being Considered	C5a: bank height above internal valley/ditch invert	2012 Disposal Area Closure Design Report, by Consultant E	A	1	Acceptable
	C5b: internal valley/ditch slope perpendicular to section		A	1	Acceptable
	C5c: potential settlement/developed pond depth		A	3	Acceptable
	C5d: horizontal distance from internal valley/ditch invert and/or developed pond from top		A	3	Acceptable
	C5e: seepage gradient through structure from potential developed pond for applicable soil		A	2	Acceptable
	C5f: fall-down slope instability to edge of developed pond		B	1	Acceptable
C6: Overtopping Failure from Bank Settlement and/or Outlet Plugging, if not Covered by C4a, C4b, C5a, C5b - **Quantify by** estimated bank settlement vs. bank height & estimated height above fluid/potentially-mobile solids leading to loss of contents		2013 Hydrology Study Report, Consultant D	B	2	Acceptable
C7: Excessive Headward Erosion Leading to Loss of Contents, if not covered by C1h or C2h, caused by creating a dome or raising contents in Disposal Areas above original structure without adequate drainage control - **Quantify** by horizontal distance of crest eroded from flow off dome and over dam slope		2012 Erosion Study, Consultant B	Not Applicable		

* Hydrological conditions and assumptions are important design considerations requiring a separate technical report. Other separate technical reports on erosion, seepage analysis, and slope stability are still required.
** Failure mode design considerations require a risk-based approach and Failure Sub-modes must be determined by existing or potential hazards
*** **FS** : Factory of Safety, **3D length @ toe** : estimated length of structure crest x length of failure extents (from toe to failure scarp), **m^3** : estimated volume of contents lost

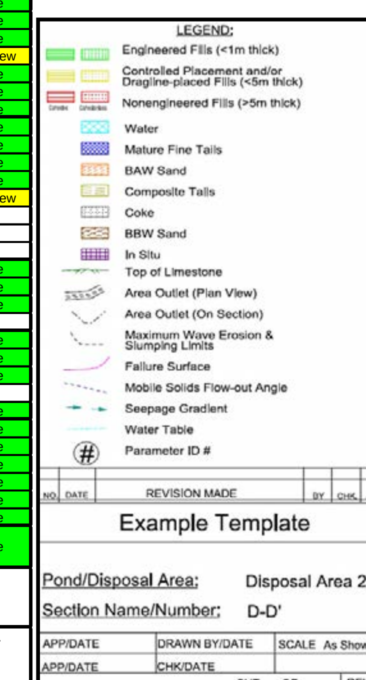


Figure 4.1 – Example of failure mode analysis for a cross section of a hypothetical tailings facility to be de-licensed

4.3 Risk assessment

Risk assessments would be conducted at various stages to evaluate proposed risk reduction measures to determine whether they meet the de-licensing objectives, and to evaluate implemented measures in view of monitoring data to confirm they have met their objectives. The key purpose of the risk assessment is to confirm that the ongoing residual risks related to the solid earthen structure are acceptable to the regulator and society. The life of the de-licensed/post-closure solid structure is very long – much longer than the operational phase – and the resulting landform will be a permanent feature of the landscape. The objective is to eliminate the need for human intervention to maintain a structure that has integrity and is compatible with the risk levels in the surrounding natural areas.

After risk reduction measures are implemented, the probability of a significant failure of a de-licensed structure should become close to the probability of similar events in natural analogues (e.g., hills, and riverbanks) for similar consequences. For example, slope instabilities occur naturally in the oil sands region due to the presence of various weak glaciated materials in the natural terrain. Therefore, slope failures of similar magnitude, frequency and consequence would be acceptable in the final landform created from a reclaimed tailings facility. The size of the affected area is used as a primary consideration to describe the failure consequence, as provided in Tables 4.1a and 4.1c.

The risk assessment process starts by determining all potential failure modes and sub-modes and their possible consequences by utilizing a FMEA or a similar technique. Assessment of the probability of each failure mode under various triggering events and appropriate risk categories must be conducted using qualitative or semi-quantitative methods and sound engineering principles and judgments. The assessment must be signed off by recognized Geotechnical Engineering experts.

The level of residual risk achieved for the facility being de-licensed is assessed using a risk matrix that is described in detail in the next section. Should a facility not meet an acceptable residual risk category, additional risk reduction strategies are to be considered and implemented to further reduce the consequence and/or probability of failure, until an acceptable risk category is achieved.

4.3.1 Risk Category Determination

The fundamental metrics of the risk assessment are outlined in Table 4.1 (a to d). This table shows the determination of the final risk category achieved for each failure mode, for each relevant cross-section and its eligibility for de-licensing from a dam to a solid earthen structure and eventually to a final landform. The risk category chart is shown on Table 4.1d.

An example of the use of the risk categories shown in Table 4.1 and the overall risk assessment process is described in the next section.

Table 4.1 – Risk Assessment

Table 4.1a - Consequence Event

CONSEQUENCE EVENT RATING	DESCRIPTION OF EVENT		CONSEQUENCE OF EVENT	
	LOSS OF FUNCTION**	HUMAN INTERVENTION	POPULATION AT RISK (PAR)*	ENVIRONMENTAL ECONOMICS
E) Very Serious	Significant	Impracticable structure repair	Permanent within area of influence (less than 10)	Loss of contents beyond the original structure footprint is > 1 km x 1 km Significant water body and environmental impact for 100 years or more
D) Serious	Small loss	Requires repairs or maintenance to maintain full function	Temporary or None	Loss of contents beyond the original structure footprint is < 1 km x 1 km Water and environmental impact expected to last < 100 years and to reduce over time
C) Minor	Insignificant reduction	Overall structure integrity maintained No human intervention or maintenance required	None	Any loss of contents beyond the original structure footprint is localized to one area and is < 1 km x 1km No significant impact on water body or surrounding environment
B) Limited	No loss	Overall structure integrity maintained No human intervention or maintenance required	None	No movement of contents beyond the original structure footprint and represent a flow < 500 m x 500 m No significant impact on water body or surrounding environment
A) Natural Analogue	No loss	Overall structure integrity maintained No human intervention or maintenance required	None	No movement of contents except through normal erosion processes No significant impact on water body or surrounding environment

* Definitions for Population at Risk (PAR applies to current land use only. Any future land use is under government regulatory control):
None: There is no discernable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.
Temporary: People are only temporarily in the consequence event area of influence. May need to be addressed case-by case by a regulator, i.e. current roadway risk may not be relevant to closure risk.
Permanent: People must reside within the area of influence of the consequence event.
** Loss of function means structure no longer maintains the ability to contain contents within original footprint from a rapidly occurring event.

Table 4.1b - Probability

PROBABILITY		
4) Low Likelihood	Event could happen in 10 years (10% probability in 10 years)	P < 0.01
3) Unlikely	Event could happen in 100 years (10% probability in100 years)	P < 0.001
2) Remote / Highly Unlikely	Event could happen in 1000 years (10% probability in1000 years)	P < 0.0001
1) Extremely Unlikely	Event probably won't happen in 1000 years (1% probability in 1000 years)	P < 0.00001
Probability of failure mode leading to consequence event. P = annualized probability		

Table 4.1c - Risk Matrix

RISK MATRIX						
PROBABILITY	4) Low Likelihood	Acceptable	Requires Further Review	Not Acceptable	Not Acceptable	Not Acceptable
	3) Unlikely	Acceptable	Acceptable	Requires Further Review	Not Acceptable	Not Acceptable
	2) Remote/ Highly Unlikely	Acceptable	Acceptable	Acceptable	Requires Further Review	Not Acceptable
	1) Extremely Unlikely	Acceptable	Acceptable	Acceptable	Acceptable	Requires Further Review
Risk = Consequence x Probability		A) Natural Analogue	B) Limited	C) Minor	D) Serious	E) Very Serious
		CONSEQUENCE				

Table 4.1d - Risk Category

RISK CATEGORY	
Not Acceptable	Not acceptable for de-licensing and requires further risk reduction by reducing consequence and re-testing in Risk Matrix
Requires Further Review	May or may not be acceptable for de-licensing. May or may not require risk reduction by reducing consequence and re-testing in Risk Matrix. This category can be de-licensed if further study allows, and the "Very Serious" consequence category may require a process as determined by the applicable regulatory agency
Acceptable	Acceptable for de-licensing with final case by case approval from regulator

Risk Category is qualitative but based on sound engineering principles

4.3.2 Risk Assessment Process

Each landform component failure mode is tested using the risk matrix, to determine the final risk category and to document it. This process is used to identify and support the need for these modifications when they are required. The recommended six step process of assigning a final risk category to a given failure mode is:

1. Evaluate all potential failure events, with input from additional technical studies when required. Include failure size when applicable. Table 4.1 provides an example of various common failure modes/events, including separate potential failure sizes. For other cases, other failure modes may be applicable. The risk for different sizes of potential failures may need to be individually assessed, since small failures may have higher probabilities of occurring, yet will not lead to significant consequences,

whereas larger failures may have much lower probability but have much more severe consequences. It is necessary to determine which combination of consequence and probability poses the highest risk. Consider cumulative failure mode effects.

2. Determine the Consequence Event Rating for each failure mode or sub-mode using Table 4.1a. There are five consequence levels, which in decreasing order are:
    - Very Serious
    - Serious
    - Minor
    - Limited
    - Natural Analogue.

   The elements that determine the consequence rating are:
    - Loss of function of the structure
    - Degree of human intervention required on the structure after an event occurs
    - Population at risk
    - Environmental economics.

   These categories are similar to the CDA (2007) categories for consequence classification of active dams. One noticeable modification from the conventional categories is the element of human intervention. As these structures are future closure landforms, the intent is to reach a state of minimal or no human intervention in response to the consequences of various events.

3. Determine the Probability of Occurrence of the event using Table 4.1b. This table has four probability categories:

   i) Low (10% probability event could happen in 10 years)

   ii) Unlikely (10% probability event will happen in 100 years)

   iii) Remote/Highly Unlikely (10% probability event will happen in 1000 years)

   iv) Extremely Unlikely (1% probability the event will happen in 1000 years).

   The probability rating of each potential event is to be evaluated by qualified engineers with input from additional technical studies, when required.

4. Use the Consequence Event Rating and Probability from the previous two steps to look up the Risk Category in Table 4.1c (Probability is the y-axis, and Consequence is the x-axis). The categories of risk in Table 4.1d are (listed from highest to lowest risk):
    - Not Acceptable (RED)
    - Requires Further Review (YELLOW)
    - Acceptable (GREEN).

   Record the results to document the evaluation.

5. Repeat for all possible failure modes and combination of possible failure modes for all applicable cross-sections and for the overall tailings facility area (as applicable).

6. The highest Risk Category (i.e., the worst ranking from any single event or combination of events) determines the overall ranking for the structure.
    - If a ranking from Table 4.1c falls in the "Not Acceptable" risk category, then further risk mitigation work is required on the structure. In essence, the structure is still considered a licensed dam based on its risk classification.
    - If the ranking falls in the "Requires Further Review" risk category, the dam may be deemed acceptable for de-licensing in principle, pending further review on a case-by-case basis by the regulator applying site-specific regulatory evaluation.
    - If the ranking falls in the "Acceptable" risk category, adequate risk reduction measures have been employed, and the structure is considered a suitable candidate to be submitted to the regulatory agencies for consideration for de-licensing as a dam.

The risk assessment process is complete when all potential failure modes and failure sizes, all relevant cross-sections, and all overall deposit area considerations that could lead to unacceptable performance have been properly categorized, documented and passed through the risk category in Table 4.1d and are found to be "Acceptable". All relevant information should be documented in a clear format for review internally and by regulatory agencies. A table format similar to the example sheet shown in Figure 4.1 is suggested for each relevant cross-section.

4.4 Risk control/reduction

Risk reduction measures required for a solid earthen structure to qualify for potential de-licensing as a dam vary for each structure type and scenario (Section 3.4). A key risk reduction measure in the transition of a tailings dam to a solid earthen structure is fluid removal and the related challenge of creating a stable outlet that performs well throughout the life of the structure. Additional measures may be required to prevent significant future accumulation of water in the facility, so it does not revert to a fluid impoundment structure in the long term. Other risk reduction measures might be required to achieve a final structure that is sufficiently robust to meet the de-licensing objectives under all reasonable potential conditions that could occur during the life of the facility. These risk reduction measures can be incorporated during initial construction, during operation or in preparation for de-licensing.

Figure 4.1 shows an example of a tailings facility that was formerly a ring dyke tailings dam, typical of the oil sands of Alberta. This facility had fluid and soft tailings removed from the impoundment area and an outlet built at the location where the containment structure was breached. The large interior area was re-shaped such that it drains toward the outlet.

Following is a list of risk reduction measures that may require consideration for some structures of this type:

- ***Remove fluids and soft tailings***. Most or all of the water and fluid fine tailings would generally be removed from the facility. A small pond may be allowed to form in the interior area provided its size is small compared to the overall area, it is located at a significant distance from the former containment structures, and its depth is small compared to the vertical distance between the pond surface elevation and the elevation of the former containment structures. The small pond would provide benefits such as wildlife habitat and some attenuation of flows to the outlet facility.

- ***Address potentially liquefiable or mobile solids***. Deposits that are assessed as being potentially liquefiable or mobile may be removed, treated (e.g., densification, consolidation, etc.) or kept at a location and at such a quantity that there is a negligible likelihood of this material ever leaving the facility or having any significant consequence in case of a triggering event.

- ***Breach the containment structure.*** The containment structure would be breached so that it does not impound any significant amount of fluid even under the Probable Maximum Flood (PMF) in the area. A breach section with more than one low spot, or more than one breach section may be considered in an instance where one of the outlets becomes blocked by slope instability or beaver activity.

- ***Build an outlet facility***. Design and build a very robust outlet system that is capable of conveying specified design events leading up to the PMF that are commensurate with the consequences of the failure. Oil sands tailings dams are generally designed to have no outlets or spillways during their operational/active period; excess water (e.g., from tailings and precipitation) is usually pumped back to the plant site for re-use. Following decommissioning, a drainage outlet would be designed and implemented to prevent excessive accumulation of ponded water from precipitation and run-off from adjacent slopes. The geotechnical side slope and hydraulic stability of the outlet facility is critical to a successful landform design. The outlet generally should be founded on robust materials (e.g., natural bedrock or cohesive glacial materials) and its outlet channel should have a modest gradient and be geomorphologically stable. The outlet location and elevation should be selected prior to the start of re-shaping the area.

- ***Re-shape the internal tailings deposits area to promote drainage towards an outlet***. The configuration of the area should be designed to limit the potential for ponding water within prescribed distances from the landform crest. Re-shaping of the interior area can be done by excavating and/or placing materials such as overburden or tailings beaches. Creation of a deep drainage valley system within the internal area using caps, hummocks, deep ditching and/or overall wedge sloping designs helps reduce the risk of excessive water ponding in the facility.

- ***Address potential settlement***. Large areas of tailings deposits that could potentially settle need to be densified, shaped, built-up or otherwise designed into the drainage scheme to avoid significant settlements that could otherwise lead to excessively deep or large ponding of water within the interior original tailings deposit area.

- ***Address slope stability issues***. Slopes should be designed for long term geotechnical stability under all potential static and dynamic conditions such that their stability is compatible with the stability of natural analogues. The stability of slopes should not rely on a functional internal drainage system in the long term. The design seismic ground motions should have an Annual Exceedance Probability (AEP) aligned with the magnitude, probability and potential consequence of the seismic event. Deformation and stability under the relevant seismic loading should be evaluated using state of practice methods. Some deformation under extreme seismic loading is acceptable, provided its effects do not lead to unacceptable consequences. Possible slope movements under static or dynamic conditions should be similar to those in natural slopes and should not result in significant progressive degradation of the overall structure integrity. Over the long term, the structure should maintain overall integrity without requiring maintenance or monitoring.

- ***Address erosion issues.*** Many of the active dams in the region experience some level of slope erosion due to overland flow of precipitation, snowmelt and in some cases exiting seepage waters that lead to the formation of rills and gully erosion. The potential risk that headward cutting of an erosion gully could intersect potentially mobile materials behind the landform crest, leading to potential for flow-slides, or a new unprotected outlet, is to be addressed in the design of the de-licensing measures. Slope erosion risk reduction measures, when required, could include: minimizing overland flow paths; limiting sub-watershed catchment sizes; capping slopes with reclamation material and dense vegetation; controlling phreatic surfaces to avoid spring sapping and soil salinization; creating large 'bunds' to prevent exit from plateaus areas over unprotected slope; and providing adequate armouring to key areas. The design should not rely on the original internal drainage systems installed for long term performance in case such systems become plugged. Particular attention should be placed on erosion of slope toes.

- ***Address future groundwater conditions***. Seepage assessments should be conducted for the design of the solid earthen structure to determine that, under all potential seepage conditions, no future slope failure or significant mass movement could result. Potential seepage conditions may include those resulting from degradation of internal seepage control systems (e.g., pipes and/or granular filters) that were included in the original dam structure, occurrence of closure Inflow Design Flood – which can be up to the Probable Maximum Flood – and surface erosion. Seepage gradients must be sufficiently low under the worst reasonably foreseeable conditions to maintain an appropriately low residual risk level. The assessment of the seepage gradients should consider the potential for non-uniform materials and variable permeability along the flow path, even in material zones that were designed to be homogeneous. Future groundwater conditions may be improved by altering the facility content properties in place by using a combination of capping and drainage, densification, aggressive sloping of overall relief, allowing time for consolidation, internal dewatering, or other measures.

4.5 Risk communication

The concept that the ongoing residual risks associated with the closed solid earthen structure are similar to those of natural landforms in the region is central to the closure strategy. This principle and the residual risks for each solid earthen structure should be communicated to stakeholders to establish clear and reasonable expectations for the long term performance of de-licensed structures. The framework proposed in this document is technical in nature and can facilitate comparisons of closed earthen structures to other similar structures and to acceptable societal risks which, as policy, may require further discussion over time.

5.0 DE-LICENSING SUBMISSION REQUIREMENTS

5.1 Submission items

When applying to the regulator for de-licensing of an oil sands tailings dam, it is recommended that the dam operator includes the following items:

- Dam records (design, construction and operation)
- Dam performance history (instrumentation data, inspection reports, maintenance)
- Structure modifications to support decommissioning and de-licensing
- Report on risk assessment
- Application document.

5.2 Dam records

The operator should include a detailed reference list as well as document storage location(s), for all relevant information from the beginning of construction and operation of the dam, up to the time of the submission to de-license the dam. Sufficient overview information about the solid earthen structure must be included in the de-licensing submission such that referral to the original detailed documents for the dam is not required. Information to be included (as a minimum):

- Structure License(s)
- Plan views
- Cross-sections showing internal geometry and foundation conditions
- Adjacent pond or deposit area elevations and geometries
- Typical and maximum pond volumes
- Pond infilling history
- Typical and maximum pond elevations and pond depths

- Pumping outflow rates (if applicable)
- Surface area of pond or storage area
- Maximum, minimum and typical dam heights and slopes
- Range in downstream slope angles
- Results of testing to confirm the engineering properties of the structure, its foundation and its contents (beaches, infill, etc.)
- Relevant design information.

5.3 Dam performance history

During the operations phase, oil sands operators submit to the regulator annual performance reports for each dam as well as periodic independent dam safety reviews. Alberta regulations also require that operators have an active monitoring and surveillance plan for the dam. As a result, there will be a very detailed performance history of each structure through its operational life and up until the point it is considered for de-licensing. Past performance history is critical to determine potential future responses to events.

The operator must include a detailed references list and document storage location(s) for the following:

- Annual Performance Reports (APR)
- Dam Safety Reviews (DSR)
- Operating, Maintenance and Surveillance Manuals (OMS Manual)
- Emergency Preparedness and Response Planning documents (EPP, ERP)
- Instrumentation and monitoring data
- Inspection reports.

The submission to the regulator must include a summary of the above information, as well as details on the following (as a minimum):

- Upgrades and rehabilitation activities
- Movement areas, downstream or upstream failures, or liquefaction events

- High-reading piezometers, piping events and/or high seepage or exit gradients
- Overtopping events
- Significant erosion or gullying events
- History of any remedial measures
- Performance history of incorporated long term design features (e.g. swales).

5.4 Structure modifications to support de-licensing

In preparation for an oil sands tailings dam being considered for de-licensing as a dam, there are many measures to be engineered and implemented to transform the structure from a dam to a solid earthen structure. These measures can vary significantly, depending on the condition of the structure and its requirements to be moved towards a landform. Some typical measures have been discussed in Section 4.

The operator must provide detailed reports on the design and the construction of the engineering measures to permanently decommission a dam and all risk reduction measures implemented to address each of the potential failure modes. In addition to that, the operator must arrange for inspection of the construction of the measures mentioned above by the regulator. Monitoring data, including information associated with these modifications, must also be provided to demonstrate the performance of the new solid earthen structure, when applicable.

5.5 Report on risk assessment

It is the dam operator's responsibility to submit a report on the risk assessment to the regulatory bodies and apply for de-licensing. In the event a structure does not receive approval for de-licensing, further application of risk reduction strategies may be required, which would be re-tested by the process outlined in this document. The risk assessment process outlined in this document provides focus on those areas that require further mitigating measures.

Figure 4.1 provides an example for a possible format to summarize the information for each cross section and to indicate the location of that section on the proposed final structure along with its location relative to the outlet and the internal drainage profile (when applicable). A number of sheets may be required to assess all areas of the solid earthen structure.

6.0 REFERENCES

AER 2000. *Oil Sands Conservation Act.* Energy Resources Conservation Board, Queen's Printer, Edmonton.

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CDA 2007. *Dam Safety Guidelines & Technical Bulletins.* Canadian Dam Association, Ottawa.

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Appendix 1

DEFINITIONS

- ***Dam*****:** a barrier constructed for the retention of water, water containing any other substance, fluid waste, or tailings, provided the barrier is capable of impounding at least 30,000 m^3 of fluid and is at least 2.5 m high. The term dam includes appurtenances and systems incidental to, necessary for, or connected with the barrier. The definition may include dams less than 2.5 m high or with an impoundment capacity of less than 30,000 m^3 if the consequences of dam operation or failure are likely to be unacceptable to the public. The definition excludes cases where the width of the barrier is so large that all risks associated with the barrier are negligible and a potential breach of the barrier is not practically possible now or in the long term.
- ***Oil sand tailings dam****:* a fluid or tailings retaining structure that exists at oil sands mining sites for the purpose of storing solid and fluid materials resulting from the bitumen extraction process. Other terms, such as dyke, are also used interchangeably to refer to oil sands tailings dams. The dam is understood to be an approved/licensed structure under the *Water Act*. [Note: pre-1993 dams in Alberta were given a "license" to operate under the *Water Resources Act*; post-1993 the wording was changed to "approval" under the *Water Act*. For the purposes of this document "license" and "approval" are considered the same and used interchangeably].
- ***Operating/active tailings dam:*** a tailings dam that is actively receiving liquids or tailings, and may have water reclaiming facilities. The dam may still be under construction and not yet built to final design height. An operating/active tailings dam requires regular reporting of its structural and operational condition, including submission of independent dam safety reviews to the regulator.
- ***Non-operating/inactive tailings dam:*** a tailings dam that is no longer actively receiving tailings or fluids other than natural precipitation. There has been a cessation of operation but the facility may still have water reclaiming facilities to control its water level. It is a dam and, therefore, it continues to require regular reporting of its structural and operational condition to the regulator.
- ***Decommissioning:*** a non-operating dam that is scheduled to be reclaimed would go through a transitional stage when various measures are implemented to convert the

tailings dam into a solid earthen structure that does not and will not in the future meet the definition of a dam. The plan and design of the measures need to be submitted to and authorized by the regulator for implementation. The decommissioning period will include active care and passive care stages. The decommissioning process eventually leads to de-licensing of the structure as a dam.

- ***Active care:*** the post-closure period when on-going monitoring is required to determine structure performance and whether active intervention may be necessary to achieve a final sustainable solid earthen structure. De-licensing of the structure as a dam may occur during the active care period.
- ***Passive care:*** the post-closure period following active care during which the performance of the solid earthen structure is monitored to confirm its compliance with the closure objectives. This period has no time limit but can be defined as being necessary until the structure is considered to be physically, chemically and ecologically stable and to pose a risk compatible with that of the natural environment in the region.
- ***Solid earthen structure:*** a mine waste dump or a structure that has previously been regulated as a tailings dam, yet has been de-licensed (i.e. it had measures implemented such that it no longer meets the definition of a dam and satisfies the requirements for de-licensing). A solid earthen structure may undergo further reclamation activities in the future to reach a landform status and receive a Reclamation Certificate.
- ***De-licensing:*** the process by which a tailings facility transitions from a licensed dam to a solid earthen structure. The decommissioning and the initial period of active care are part of the de-licensing process. It includes preparation of a design plan for the measures to be implemented for the transition, submittal of this design to the regulator, authorization from the regulator to install the measures and approval of the installed measures by the regulator, at which point the structure is de-licensed as a dam and it becomes a solid earthen structure.
- ***Reclamation (or final reclamation):*** the process a solid earthen structure must go through to qualify for certification as a landform and receive a Reclamation Certificate.

- ***Landform or closed/reclaimed structure:*** a solid earthen structure that has met all provincial and federal closure and reclamation criteria and received a Reclamation Certificate from the regulator.
- ***End-Pit Lake:*** A lake contained within a mined-out pit that remains within the closure landscape. Large natural and/or constructed barriers retain the fluid in the lake. The distance from the lake to the nearest topographically low area is sufficiently large that the natural and/or constructed barrier would not be considered a dam.

Appendix 2

GEOLOGICAL SETTING OF THE ATHABASCA OIL SANDS REGION

A brief description of the physical setting of the Athabasca oil sands area is included here to provide context to some of the issues associated with earthen structures in the region that affect the performance of tailings dams, the transition of these structures into solid mine waste facilities and eventually to landforms. These issues affect the potential risks associated with these structures at all stages of their life cycle.

The oil sands regional climate is classified as hemiboreal, or between temperate and subarctic zones. The mean annual precipitation is 437 mm (1944-2009, Fort McMurray Airport). Potential evapotranspiration exceeds precipitation on a monthly basis from April through September as well as on an annual basis based on long-term average precipitation values, which tends to be favourable for closure and reclamation of tailings facilities.

The topography of the Athabasca oil sands mining area is subdued with relatively flat to undulating relief. The drainage (river and most creeks) is incised. Valley slopes commonly present slope instabilities associated with the various weak glaciated strata that form the geology of the area.

The geology of the Athabasca Oil Sands region of Northern Alberta comprises mainly Holocene sediments at the surface, underlain by Pleistocene deposits, largely of glacial origin, underlain by the Cretaceous Grand Rapids (Kg) and Clearwater (Kc) Formations which are underlain by Cretaceous McMurray Formation (Km) shale and bituminous sand (oil sand) deposits. In some areas, the Cretaceous shales are not present, having been partially or wholly eroded during glaciation. The interbedded limestone and shale of the Devonian Waterways (Dw) Formation lie beneath the mineable resource, and are persistent throughout the region. The key geotechnical considerations associated with these formations are presented below.

Clearwater Formation

Regionally, the marine clay shale strata in this formation are geotechnically significant. The clay-rich strata have been affected by post-Cretaceous glacial activity, resulting in localized or extensive horizontal or sub-horizontal planes of weakness that can adversely impact the stability of slopes in these materials. These strata are typically at residual strength and tend to have significant pore pressure responses to loading, which typically do not tend to dissipate within the time frames of most projects. Residual strength friction angles are quite low in these strata. Some of the clay in this formation can be dispersive. In terms of hydraulic properties, the Clearwater Formation has a very low permeability overall; however, relatively thin siltstone beds that are common throughout the formation and the lowermost member of the formation (Wabiskaw Member) are considered minor aquifers.

McMurray Formation

The McMurray Formation includes the mineable oil sands (ore) and zones of non-mineable material ("lean oil sands"). Both the Upper and Lower McMurray Formation host clay-rich strata, with the potential for low-strength, pre-sheared planes of weakness that may result in slope instability. Similarly, these strata may be subject to strain-softening on discrete planes, induced by stress-relief during unloading (mining). The Lower McMurray may contain water-saturated fluvial sand deposits, which are considered the primary "basal aquifer" beneath the mineable oil sands, and basal clays with low shear strength.

Waterways Formation

The Waterways Formation comprises interbedded limestone and shale and underlies the McMurray Formation throughout the oil sands mining region. The upper contact of this formation includes, in some cases, localized to extensive high-plastic paleosols, which may exhibit pre-shearing and planes of weakness similar to that described above and with similar potential impacts on the stability of slopes surrounding End-Pit Lakes. In terms of hydraulic properties, the Waterways Formation is considered an aquifer/aquitard system displaying characteristics of both regional and local groundwater regimes. Groundwater flow is largely controlled by the presence of more pervious sub-units, fractures, faults, and karst features arising from folding, collapse features, and erosion processes.