Water Management Framework for Oil Sands Mining

February 2022

Executive Summary

For Alberta's mineable oil sands industry, a wholistic approach to water management including a focus on water use reduction, water reuse, and water release is necessary for the continued sustainable development of Oil Sands mines and our continued commitments to reclamation and closure. A fundamental premise of all operating and currently approved applications for oil sands mining in the Athabasca Region is that operators work towards closure landscapes that are self-sustaining and connected to the watershed. That means that treated mine waters will inevitably be released to the Athabasca watershed to achieve self-sustaining closure landscapes. Delaying release of treated mine waters, an important component of a sustainable water management framework, will prolong the transition from mine closure to a natural boreal forest landscape. Site-wide water management practices need to ensure that all components of a water management framework can be fully considered along with associated environmental net effects to determine the best overall outcome.

This document provides context while framing a sustainable approach to water management for the minable oil sands region. Four key principles (Shared Value of Water; Watershed Scale Management; Reduce-Reuse-Return; Integrated options analysis) are used to anchor the framework and develop key rationales for mine water release that balance the trade-offs inherent in water stewardship. A technical framework is described which follows leading water release policies and regulations currently used for other industrial, municipal, and agricultural users of water that have the ability to release water. These policies and regulations have been developed and refined within North America for decades and provide detailed limits on released water that is protective to all users and incorporates adaptive feedback into the process. Any future regulated release of treated mine water would be held to the same robust standards. Considerations will include the development of end of pipe limits based on regional watershed management; site specific characterization of water and opportunities for water reduction, reuse, and release; and monitoring at the end of pipe coupled with environmental effects monitoring in the river to detect and prevent watershed effects.

Content

1 Introduction

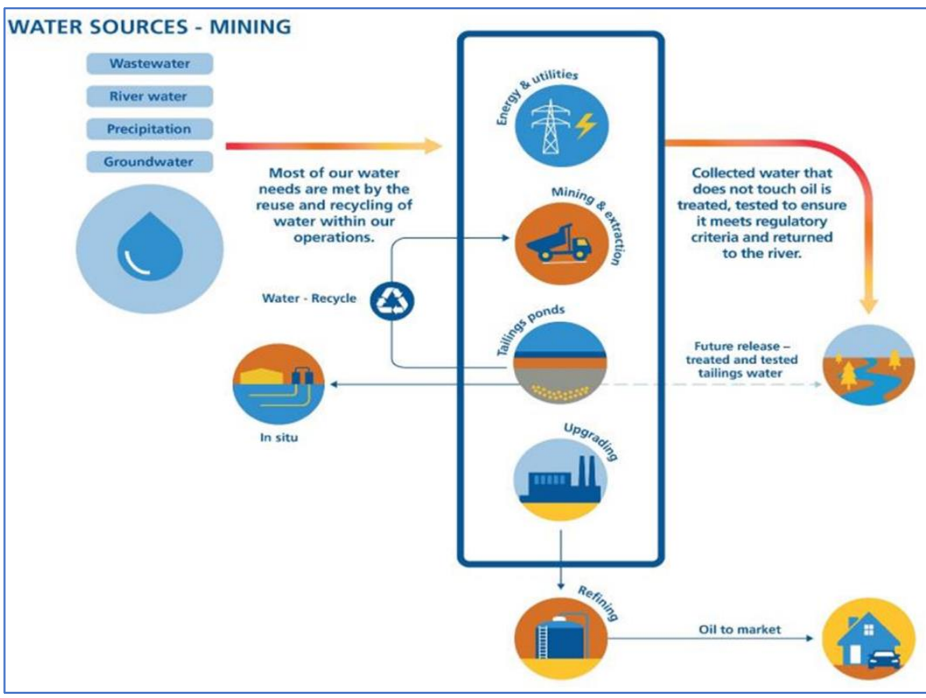
1.1 Purpose

This document describes a sustainable water management framework for the mineable oil sands region, provides rationale to release treated mine water to the environment and explores alternatives to mine water release.

1.2 Background

Alberta has vast proven oil reserves, largely contained in oil sands under the boreal forest in the northern part of the province. A portion of the reserve is recoverable using open pit mining and extraction techniques; the remainder of the resource requires in situ methods.

In open pit mining, bitumen is recovered from the oil sands using a commercialized version of the Clarke hot water extraction process. The bitumen is recovered using floatation principles and the tailings materials, water, sand, silt, clay and any unrecovered bitumen is then hydraulically transported as a slurry within a pipeline to a tailings containment facility (tailings pond). Following deposition, the sand settles quickly capturing some of the silt and clay and process water within the pore space between the sand particles. The balance of the silt and clay (fines) are transported further into the tailings pond where they begin to settle. A clarified layer of water forms, known as the "free water zone" which overlies a zone of silt and clay,



Notes:
- This schematic will vary by operator and is provided as an example only.
- Graphic provided by Suncor Energy.

referred to as fluid fine tailings (FFT) which typically 1—20% fines which gradually transitions to deeper layers of denser older material referred to as mature fine tails (MFT) which is typically > 30% fines. The clarified water within the "free water zone" is commonly known as oil sands process water (OSPW) and is reused for bitumen extraction, process cooling, and to hydraulically transport materials. Water losses in the process include water that evaporates, is chemically converted to produce hydrogen for an upgrader, and water that is contained within the pore spaces of tailings which is not available for reuse. Consequently, the overall process is approximately 80-85% efficient.

All oil sands mining operations source make-up water from the Athabasca River or its tributaries. Other sources of make-up water include rain or snow that falls in the active mining area, or groundwater which is typically pumped to depressurize mine faces to prevent pit flooding and mine face instability. However, groundwater quality varies greatly between leases, with total dissolved solids (TDS) ranging from 500 ppm (i.e. fresh) to over 80,000 ppm which is more than twice as salty as sea water. Fresh ground water in the range of 500-2000 ppm TDS can be a source of make-up water to the extraction circuit. However, most of the highly saline groundwater cannot be used as make-up water as it would increase the salt levels in OSPW to unacceptably high levels – see section 3.2 for the impacts of salts in OSPW. As a result, mining leases with highly saline groundwater typically have to manage this water using alternate approaches.

All mine operations have approval to release runoff that does not fall onto the active mine site. Further, some mine operations have approval to release fresh (less than 4000 TDS) groundwater and one mine has approval to release treated upgrader process water. To date, oil sands mining operators have not returned treated OSPW to the environment which is resulting in a build-up of water inventory on all sites. Mining operators are developing and implementing technologies and practices to significantly reduce the amount of water trapped in FFT and other forms of tailings deposits to expedite tailings reclamation. This has allowed some operators to reduce net make up water required from the Athabasca River and its tributaries. In addition, operators have been working to reduce their water footprint and reuse excess water. Notwithstanding this, there are limits and trade-offs. Reducing water use by reducing the use intensity or increasing reuse will lead to degradation of water quality; specifically the build-up of salts. As the concentrations of dissolved components increase, so does treatment system complexity and the associated energy footprint. Further, the build-up of salts in mine waters will delay the reclamation of mine sites as these salts will remain in the reclamation landscape for decades after mine closure. A balance must be maintained between environmental net effects and sustainable water management that focusses on reduction of water import, water reuse/recycle, and water release.

To release treated OSPW to the environment, a primary quality consideration is the acute and chronic toxicity effects from dissolved organic compounds, commonly referred to as naphthenic acid compounds along with other compounds that may also contribute to toxicity in OSPW such as ammonia. In all cases, OSPW would be treated to ensure compliance with government regulations including removal of acute toxicity (see section 5.2.8 for treatment methods).

For Alberta's mineable oil sands industry, the current water management approach does not include water release of treated OSPW. In the short term, industry therefore has fewer options for reducing water footprint and expediting aquatic reclamation projects. In the long term, operators are working towards developing closure landscapes that are self-sustaining and that will be connected to the surrounding watershed without clear regulatory guidance. This creates an unsustainable water management framework, increasing the likelihood of decisions leading to greater undesirable environmental net effects when compared to a sustainable water management framework that includes safe and regulated release of treated mine water.

All other industrial, municipal, and agricultural users of watersheds in Canada have the ability to release treated water that is governed by both the provincial and federal policies and regulations. These policies and regulations have been developed and refined within North America for decades and provide detailed guidance on how to release various waters to a watershed in a manner that is protective of all users and incorporates adaptive feedback into the process. These policies and regulations should be used to allow mine water release to ensure Canada's oil sands resource is developed in a sustainable manner.

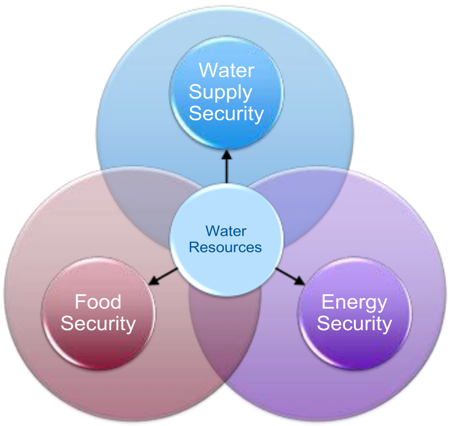
2 Sustainable Water Management for the Oil Sands Region

There are four key components to Sustainable Water Management:

1. Shared value of water
2. Watershed management
3. Principles of reduce-reuse-return
4. Integrated options analysis that employs risk assessment and net environmental effects

2.1 Shared Value of Water

Water is an essential foundation for life (environmental) and society (economic, social, and cultural). Consistent with Alberta's Water for Life Policy, water resources must be used to maintain the Water- Energy-Food Security Nexus (as depicted below). No one segment is



independent or more important than another. Sustainable water management must strategically evaluate and understand this perspective and proactively identify risks to water resources that could compromise the shared value of water.

The main risk to the shared value of water is when water is used in such a way that it cannot be re-used to create additional value. The value of water increases by maximizing the benefit generated for the amount of water used. For the mineable oil sands industry, a strategic water management framework that reduces the water footprint (e.g., reduction, reuse) and allows for water release will increase the value of water.

2.2 Watershed Management

Sustainable water management practices must be considered at a watershed scale. Historically, cumulative impacts on water quality and quantity within a specific watershed have been overlooked. The key consideration is that all users of a watershed must be taken into account and balanced together. This includes:

- Identifying all users (First Nations, industry, agriculture, municipal, environmental base flow, social and cultural);
- Substance load allocations to ensure in-stream substance concentrations do not exceed water quality objectives. (includes surface & groundwater for both quality & quantity);
- Environmental Effects monitoring (EEM) and cumulative environmental effects

assessment; and
- Assessment of effects due to potential changes in climate.

Regulators have tools to successfully manage watersheds. Improvement in data and water quality models will facilitate future scenario planning to assess potential impacts on the available water resources. This information can be translated to the larger picture of sustainability. Ultimately this allows for a more transparent, informed discussion and development of strategic water stewardship plan that can span decades.

2.3 Principles of Reduce-Reuse-Return

Effective water management is part of a larger process that considers a facility's water use in the context of a watershed. However, there is no one solution that can be applied to all individual sites. Each site is unique with respect to its development history, infrastructure, and water quantity and quality requirements. Site water management principles should address the following:

- Reduction of water use
  - Having a responsible water footprint balancing water use reduction with the net environmental effect of these reductions.
- Reuse of water
  - Reusing water to improve water efficiency but balancing it with the impact on its quality and value.
- Water Return
  - Releasing treated water to the watershed that is protective to all users and meets all environmental and regulatory requirements helping to improve the shared value of water.

2.4 Integrated options analysis

This analysis recognizes the integration of water management principles. Sustainable water management for an individual site must include the principles of reduce-reuse-return, recognizing that each site will be unique based on a number of factors including:

- Site development history and maturity (e.g., catchment area);
- Mine planning/tailings management– development, start-up, operation, reclamation and closure;
- Water system infrastructure;
  - Physical location of assets;
  - System age, materials of construction, design specifications;
- Water stream quality and quantity;
  - Includes surface and groundwater sources;
- Ore characteristics.

All of these factors will lead to the development of options or opportunities in all three areas of water management. Integrated analysis of each option helps ensure water used by industry can ultimately be released to the watershed. This is necessary to ensure self-sustaining closure landscapes. Two components of this analysis are risk assessment and net environmental effects. Risk assessment determines the relevance of site specific factors to potential opportunities. Net environmental effects provide the context for trade-offs between water management, tailings management, greenhouse gas emissions / energy footprint and land management.

3 Rationale for Mine Water Release

There are a number of rationales for releasing treated mine water that can be differentiated into two major categories and that are based on the principles of sustainable water management discussed above:

1. Water Quantity; and
2. Water Quality

Water quality and quantity are linked and must be carefully considered during the development of water management strategies for a mine site. There are many ways to effectively manage water quantity that will result in a negative impact on water quality and viceversa. However, treated water release is the only option that allows operators to balance between water quantity and quality impacts and ultimately improve overall environmental performance including reclamation success.

3.1 Water Quantity

3.1.1 Water Volume Management

The Alberta Environment and Parks Tailings Management Framework has the ultimate goal of decreasing the inventory of fluid tailings volumes associated with oil sands mining to accelerate tailings reclamation and closure. This reduction in fluid tailings will result in additional water being released from tailings deposits, thereby increasing the volume and/or salinity of the free water on the mine lease. Improvements expected in tailings management practices will accelerate the need to address the additional water during active mining. If this challenge is not addressed, onsite storage of this water may constrain site management options for some mine operators, and lead to actions that result in an unacceptable net environmental effect such as building additional above grade holding ponds solely for the purpose of storing excess water. Furthermore, as the number of tailings facilities is reduced and closed and pit lakes are created, the water will have to be released to the watershed. This is a fundamental premise of all currently approved applications for mining in the Athabasca Region. The Operators objective to create self-sustaining reclamation closure landscapes requires treated mine water released to the watershed. The only alternative to this is perpetual care of the oil sands mine sites after closure.

3.1.2 Flow sustainability (hydrological connectivity)

Mine water release will provide flow back to the watershed. Operational mining sites interrupt the hydrological connectivity from an active mining area. Run-off, precipitation and snow melt water that contacts oil sands are potentially affected by the process and are contained in tailings facilities, while only unaffected run-off water is directly released to the watershed or used as make-up water. Mine water release would provide flow back to the river which increases the shared value of water.

3.2 Water Quality

Water quality management onsite is critical for a number of reasons. As all current mine operations use extraction water in closed looped systems, water quality will tend to deteriorate over time as salts and other dissolved constituents concentrate. The salinity of OSPW is typically controlled by the following: the quality of the ore body (i.e., saline or non-saline ore), management of mine waters, especially groundwater, process aids used in the extraction process and the amount of fresh make-up added to the system. Improved tailings management practices will result in the need for less fresh make-up water (e.g., water conservation) which will lead to an increased concentration of salts and other dissolved ions in the recycle water if not addressed. Salt management is critical for the success of mining/extraction/upgrading operations as well as creating self-sustaining reclamation landscapes.

There are five major reasons to control water quality:

1. Ability to create a viable final reclamation landscape that can transition to a natural boreal forest ecosystem in a relatively short time after mine closure;
2. Ability to reuse water onsite, therefore reducing makeup water demand;
3. Scaling and corrosion control of assets;
4. Impacts on tailings settling; and
5. Impact on extraction efficiency;

All five drivers are rationale for mine water release during the operational mining phase. By controlling dissolved ion chemistry, mining operations can potentially start to achieve progressive reclamation with regards to the onsite water quality. Controlling salts early will help to progressively reclaim mine sites, reduce environmental impacts over time and expedite pit lake development. A Salt Management Study completed in 2014 using a process model with planning scenarios assessed the fate of salts retained in the recycle water for life of mine then released in the reclamation landscape versus release during active mining. The following key findings were highlighted by this study:

- The main sources of salt to the mines are connate water (thin layer of water surrounding sand grains in the ore), groundwater and makeup water (river water, runoff).
- The majority of salts remaining at oil sands mines at closure will be in pit lakes and in tailings pore waters which will continue to be released as the tailings deposits continue to settle.
- The timing of treated mine waters release has little effect on the concentrations of ions and TDS in the Athabasca River due to the assimilative capacity of the river.
- Active release of treated mine waters during operations has the potential to substantially reduce concentrations of ions and TDS in process water and pit lakes at closure; and
- Circulation patterns in Lake Athabasca constrain the potential effects of inflow from the Athabasca River i.e., the flow from the Athabasca River short-circuits into the Slave River with little mixing with the main body of Lake Athabasca

Desalination has been suggested as an effective way to treat mine waters to remove the salts before releasing treated mine waters to the watershed. This pre-supposes that the salts in mine water cannot be returned in a way that is protective of the watershed. All watersheds have an assimilative capacity for salts. In fact, it is estimated that the lower Athabasca River watershed gets more than 1,000 tonnes of salts a day naturally from saline groundwater (COSIA 2018 Water Research Report for Mining, page 43-45). Chloride levels which are the main concern for aquatic organisms from salt, are typically around 5 ppm during the high flow season and between 30-40 ppm during low flow months in the Athabasca River near the river's terminus. The reason is that natural saline groundwater discharges to the river are unaffected by seasons, so concentrations are higher during low flow. Mine water releases from multiple leases would only be a small fraction of the natural salt loading to the river and could be released only during higher flow months during mine operations, resulting in chloride levels that are indistinguishable from background concentrations. Desalination which is both expensive and energy intensive would result in a concentrated salt stream which would have to be stored on site, likely in tailings deposits. In the fullness of time, the pore waters from these tailing deposits would seep to the surface and become part of reclamation waters, thus returning to the watershed. So the result of all the effort would be the same, these salts returning to the watershed, but the reclaimed mine landscape would remain too salty for centuries.

3.2.1 Ability to create a viable final reclamation landscape

OSPW quality can be a factor in the need to manage salts prior to creating a final closure reclamation landscape. The ability of the biological components of boreal forest closure landscapes and end pit lakes to tolerate high salinity water has limits. Escalating concentrations of salts in pore waters and surface waters (e.g. pit lakes) may elevate risk to vegetative growth, ecological health and development. Mine water release as part of progressive reclamation used to control salts will improve the likelihood of early success and speed the transition after mine closure to a natural boreal forest ecosystem.

One operator had completed a more rigorous long-term model of their reclamation landscape including the water quality in the pit lakes which considered the impacts of mine water release in the closure environment and included the following key findings:

- Flushing the pit lakes with Athabasca River water for 15 years post-mine-closure while releasing the pit lake water to the Athabasca River watershed results in lower Total Dissolved Solids (TDS or salts) to below the chronic toxicity threshold in the pit lakes within 10 years of mine closure.
- In the absence of both mine water release during active mining and a fifteen-year flushing period for pit lakes in the reclamation landscape the TDS of the pit lakes would remain above the threshold for chronic toxicity for forty years after mine closure.

3.2.2 Water Reuse

Water reuse (reducing the water footprint for a facility) has a positive impact and benefits by reducing water withdrawals from the river, however negative impacts include water salinization. Management and mitigation of highly saline water streams is critical to be able to reuse water onsite. While there are some opportunities to reuse water, each operator will have a unique maximum that balances risk between a reduced water footprint and poor reliability due to the specific assets present (e.g., upgraders – see section 3.2.3), detrimental impacts on tailings (section 3.2.4) and lower bitumen recovery (section 3.2.5). As noted earlier, highly saline groundwater cannot be used as makeup to the recycle water circuit and must be managed differently.

3.2.3 Scaling and corrosion control of assets

There are a number of complexities around scaling and corrosion control of assets which are unique to each individual operation. This means that a driver for one operation may not be a driver for another. Scaling and corrosion in conveyance piping and heat exchangers due to high salt concentration (chlorides and divalent ions) can lead to equipment failure, product spills, production losses, and safety incidents if water quality cannot be controlled or managed.

Sites with integrated heat and water balances between an upgrader and extraction facility must evaluate circulating water quality and asset metallurgy to understand how a circulating water quality can be managed. An additional factor for integrated mine-upgrader sites is diluted bitumen (DB) chloride levels, which also contribute to primary mechanisms that can directly impact main upgrader process equipment reliability; in fact, excessive chlorides in DB has resulted in significant loss incidents in upgraders in the past. The ability to "wash" DB of salts and manage the waste steam in tailings facilities is a significant consideration.

3.2.4 Extraction Efficiency

There are known impacts of divalent cations (calcium and magnesium in particular) in OSPW that can negatively impact extraction efficiency. There is no one common number that can be applied to derive a limit as the impacts on extraction efficiency are a function of several factors including ore quality, temperature of the extraction water, and the use of process aids. In general, ores with fewer fines have higher tolerance to impacts from salts. This means each operator will have their own internal water quality target to control salts and ensure they meet regulatory targets for extraction efficiency. It is also known that ore body quality is variable; meaning an operator's tolerance to salts will change with time.

3.2.5 Alternatives to Mine Water Release

There are several means to delay mine water release into the future, many of which have or are being deployed by mine operators. However, as previously noted, all surface mines must eventually be reconnected to the surrounding watersheds as the mine site evolves into a natural ecosystem and meets all reclamation objectives. The reason is that precipitation in the form of rain or snow will continue to fall on the reclaimed mine site, mixing with the existing mine waters. If this water is not released to the local watershed, it must be retained on site in perpetuity. In theory, this likely means building enough surface water storage, adequate in both volume and surface area so that soil absorption and evaporation losses equal precipitation, on average. At least some of these additional surface water storage facilities would need to be contained by man-made dams which also require perpetual care. In a perpetual care scenario, there would need to be active water management on site forever and the land could never be used for other high value purposes such as traditional use or recreation.

4 Technical Framework for Water Release

4.1 Overview of Water Release Framework

The Government of Alberta has long established policy, regulations and procedures for both municipal and industrial facilities on how to permit treated wastewater released back to a receiving environment. Oil sands operators believe these tools can also be directly applied to permit release of treated mine waters; specifically the regulations and procedures work independently of the specific type of water to be released. The tools identify parameters of concern resulting in end of pipe standards that provide protection to the watershed. The Oil Sands Water Management Framework below outlines the overall process for water management.

There are three (3) major components in the framework that together create a comprehensive and adaptive water management framework:

1. Development of end of pipe limits based on regional watershed management or

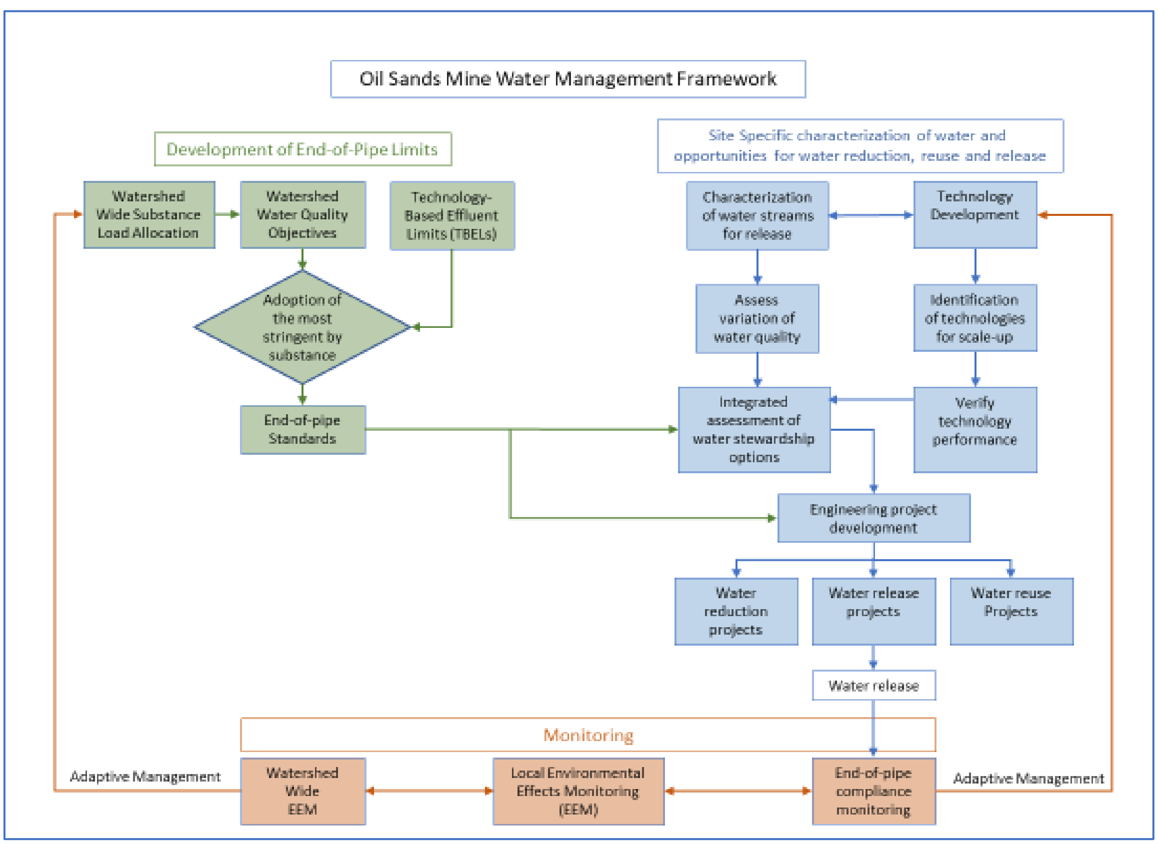
technology-based standards;
2. Site specific characterization of water and opportunities for water reduction, reuse and release; and
3. Monitoring at the end of pipe and for effect in the watershed.

As can be seen in the framework diagram all these activities are linked and feedback into processes providing an essential principal of adaptive management. While the overall framework and tools have been well established by regulatory agencies, it has not yet been applied to OSPW. The following sections will discuss major components and reference to work completed by industry.

4.2 Development of End of Pipe Limits

Development of end of pipe discharge limits is a critical step for water release. This information is a key input into site specific work each operator must complete to be able to develop an overall sustainable water management plan that can balance the trade-offs between water and energy usage.

End of pipe limits are the result of a process that looks at both the watershed derived water quality objectives and treatment technology based standard. The more stringent objective or standard is selected parameter by parameter to provide protection to the watershed. This approach is used in Alberta to approved wastewater discharges on a site-specific basis



4.2.1 Watershed SLA Derived End of Pipe Limits

A substance load allocation (SLA) determines the conditions and ability of the watershed to receive discharges without adverse impacts. At its core, an SLA is a back calculation from a downstream point to determine acceptable mass discharge from an upstream source (i.e. kg or tonnes per day) that does not adversely impact the watershed. The SLA is a very powerful tool to develop scenarios and understand what the potential acceptable loadings to a watershed could be under a wide range of development scenarios (wastewater discharges) as well as river flows. As SLA models are developed over time they incorporate both natural and anthropogenic discharges from both point and non-point sources as well as mixing conditions within specific river reaches.

SLAs have been derived for the Athabasca River using the Athabasca River Model (ARM). ARM is at an advanced stage of development with very strong calibration between modeled results and actual measured concentrations and has been used historically for permitting in Alberta. Suncor's effluent discharges (Upgrader, Flu Gas Desulphurization) have been studied and approved using this model that assumed several other simulated operator discharges. COSIA's SLA project reviewed existing SLAs and then executed work to further improve the model and inputs to calculate a large number of development and flow condition scenarios that can be accessed in a database tool (SLA Explorer tool). Through COSIA collaboration the model was able to include planned and hypothetical discharges by COSIA members between 2020 and 2040. The components of this work were validated by third party reviewers. COSIA is continuing to make improvements to the tools as more information on planned releases or improved data is collected. A condensed version of the COSIA SLA project report is available on the COSIA website.

4.2.2 Technology Derived End of Pipe Limits

Technology based end of pipe limits are also known as TBELs: Technology-Based Effluent Limits. These limits are based on the application of appropriate pollution prevention and control strategies and consider the age and type of facility (i.e. industrial sector such as upgrading, coal mining, pulp and paper etc.). These limits do not inherently consider ambient constraints, except to the extent that good technology limits will offer protection by virtue of the use of modern technology. Further, sector-specific technology limits are end-of-pipe limits and do not describe or prescribe specific technologies, except by way of describing the basis for the end-of-pipe limit. However, to date in Alberta, there has never been an application for release of treated OSPW and therefore no derivation of technology-based end of pipe limits. A COSIA Technology Based Standards project was developed to understand potential technology-based limits for OSPW. The project evaluated approaches used in North America and Europe for other industrial sectors including refinery pulp and paper and mining (coal, metals) industries. This project considered both closure scenario and operational releases as both must be defined. A second COSIA study that focused on novel / early-stage, near commercial and commercial treatment technologies for OSPW dissolved organics was completed in 2014. Summaries of both studies are available in Mine Water Research Summaries published on the COSIA website (see section 5.2). In 2018/19, AEP also completed a TBELs study that considered approaches used by other industrial sectors including oil and gas extraction, oil refining, mining, and pulp and paper. This report notes that the oil sands industry is sufficiently unique that it cannot be easily made part of an existing industrial category. However, many of the wastewater treatment techniques used in other industries (and the end-of-pipe limits they produce) can potentially be adapted for treatment of oil sands wastewater.

4.3 Site Specific characterization of water and opportunities for water reduction, reuse and release;

Each oil sands operation will have a set of unique conditions as well as risk tolerance that must be understood to develop a water management plan. These plans evolve to the level of stewardship when they are able to incorporate watershed level information as has been developed with COSIA SLA project as well as a robust monitoring plan. The framework diagram identifies key components of site specific activities:

1. Characterization of Water Streams;
2. Technology Development and Verification; and
3. Integrated Assessment of Water Stewardship Options.

4.3.1 Characterization of water streams

This activity generally starts simplistically as data collection of water quality and quantity for all streams on a site, but ultimately develops into modeling tools or a site wide water quality/quantity balance. A key aspect of this step is to explore scenarios around changes to site water systems as various types of projects are implemented and provide inputs into risk based assessments of potential strategies. These tools are necessary to understand the net environmental effect of a proposed water management project.

4.3.2 Technology Development and Verification

There is a wide array of existing treatment technologies used for water treatment as well as new technologies at various stages of development. Oil sands operators must navigate the array, looking to take advantages of new technology or improvement of existing processes. An important aspect for technology development is to explore and understand how technology could be exploited for water reduction, water reuse and water release that allows each operator to balance all risks of a water management plan while minimizing other environmental effects including Green House Gas (GHG) and waste generation. In many cases a technology can solve one problem while creating two or more issues; holistic evaluation is required.

A second important aspect of this step is performance verification. Testing of technologies for their ability to perform at a commercial scale is important because ultimately there are performance parameters that cannot be predicted via lab or pilot studies. Testing of toxicity reduction with biological methods is part of a performance verification step. Biological testing methods can include static laboratory and/or dynamic mobile laboratory through to a pilot river facility.

4.3.3 Integrated Assessment of Water Stewardship Options

This step is the critical meeting point where derived end of pipe limits; water system balance; and technology assessment come together. This step starts with developing a clear definition of the water issue(s)/risks being faced by the operator. Once this has been defined, permutations utilizing various operation mode-technologies for water reduction, water reuse and release can be defined and evaluated. Understanding the net environmental effects allows for comparisons given unique site conditions that differentiate between options. Ultimately this process results in a number of projects that can be classified into the three broad categories of reduction, reuse and release. Understanding the unique conditions of an operating facility can only be completed by individual operators. While there is an opportunity for operators to learn from each other's experiences, it does not mean a project identified for one site would result in the best net environmental effect for any other site.

4.4 Monitoring

End of Pipe Compliance Monitoring and Environmental Effects Monitoring (EEM) ensure that the treated release water meets all regulatory requirements, that there are no unexpected effects in the watershed and that the watershed is protected. Further, these two monitoring approaches provide feedback in the water management framework and give it a key principle of being adaptive over time.

End of pipe compliance monitoring serves two roles. First, all end of pipe monitoring requires compliance with TBELs based or water quality-based end-of-pipe limits. In almost all cases, whole effluent toxicity testing (WET) is also required at end-of-pipe. WET testing is meant to measure the effect of all substances as only a small number of parameters are usually regulated versus the multiple compounds that could be in a wastewater stream; and can detect potential unknown interactions between parameters. WET testing is another mechanism to confirm the treatment process is operating as per intent and to help ensure wastewater discharges will have minimal impacts in the watershed. The second role of end of pipe compliance monitoring is to provide feedback into the technology development cycle. Long-term full-scale performance data for various unit processes helps identify gaps or operational improvements that can be addressed.

Environmental Effects Monitoring (EEM) of a new release typically requires baseline monitoring immediately upstream and downstream of the planned release point in advance of the release. This ensures that the potential effects of the release (once it begins) can be confirmed through monitoring and that any effects are protective of the watershed. Local monitoring is also supplemented with regional-scale monitoring, which for the Athabasca River is managed by the Oil Sands Monitoring (OSM) program and is particularly important when there are multiple releases to the watershed. EEM is designed to detect change in the parameters being measured using triggers that are below effects thresholds so that, if needed, investigations into the cause of the change occurs before any adverse effect occurs.

5 Multi-Stakeholder Activities in Support of Oil Sands Water Management Framework

5.1 Water Release Working Groups

5.1.1 Oil Sands Water Release Technical Working Group (OSWRTWG)

In 1996, the OSWRTWG comprised of industry and government scientists developed a document outlining the work that Oil Sands operations need to complete in order to sustainably release water back to the environment. This document includes the characterization of oil sands water and outlined the approaches and tools to assess and evaluate water releases. An appendix to the document laid out the knowledge gaps as of 1996 and a list of recommended studies to address these gaps.

5.1.2 Oil Sands Process Water Science Team (OSPW-ST)

The OSPW-ST was formed by AEP in February 2018 and was disbanded in August of 2019. Its key purpose was to provide credible scientific information to inform appropriate government regulatory bodies (the Alberta Energy Regulatory, Alberta Environment Parks, Environment and Climate Change Canada) regarding the potential release of treated OSPW by Syncrude Canada via a pilot using a carbon-based filtration process. The group was tasked with:

(a) Determining relevant biological and ecological endpoints for toxicity testing for the pilot.
(b) Designing a framework for an effects-based monitoring system (building upon design and decision criteria and approaches used in the Federal/Provincial Environmental Effects Monitoring Programs and a design for enhanced monitoring in the Athabasca River, to be employed both prior to the possible pilot release to better define baseline conditions and following any approved releases.
(c) Designing the requirements, parameters and conditions required for a quantitative modeling system which will be used to assess and predict the environmental effects of the treated pilot water prior to and after any approved release to the Athabasca River.

5.1.3 Oil Sands Mine Water Science Team (OSMW-ST)

The OSMW-ST was formed in August 2020. Assistant Deputy Minister, Policy Division, Alberta Environment and Parks requested that Alberta Environment and Park's Chief Scientist form an OSMW ST. The role of the science team is to provide technical advice to inform the development of regulatory guidance documents that would identify the conditions under which sectoral scale releases of treated oil sands mine waters could be safely released to the Lower Athabasca River. The mandate of the OSMW-ST is to review and provide feedback on: a) draft work plans and b) final technical reports, in draft form, that present the results of work deployed to fill information gaps. There are six work plans:

1. Modelling receiving environment concentrations for baseline and release scenario conditions based on the identification of existing oil sands mine water releases and future oil sands mine water streams which might be released to the environment
2. Human and ecological (including aquatic) health risk assessment
3. Technology-based effluent limits assessment, including a discussion of Best Available Technologies Economically Achievable (BATEA)
4. Enhanced baseline environmental monitoring
5. Local and regional-scale environmental monitoring
6. Treated effluent toxicity assessments and effluent chemical characterization

5.2 COSIA Projects Supporting the Oil Sands Mine Water Management Framework

COSIA was formed in 2012 to accelerate the pace of environmental performance improvement in the oil sands through collaborative action and innovation through four environmental priority areas (EPAs): GHG, Land, Tailings and Water. Current members of the Water EPA are Canadian Natural, Cenovus, ConocoPhillips, Imperial, Suncor, Syncrude and Teck. The Water EPA aspires to be world leaders in water management, producing Canadian energy with no adverse impact on water. Since inception, the Water EPA priority for the mining sector has been to improve the state of knowledge and to improve existing or develop new technologies in support of the oil sands mine water management framework. To that end as of December 31, 2020, 273 projects have been completed at a cost of $592 million and the results including intellectual property shared among all the members. Currently there are 86 active projects with a total cost of $319 million. An overview of all Water EPA projects for the mining sector can be found in Water Research Reports on the COSIA website:

2018 Water Research Report for Mining
2019 Water Research Report for Mining
2020 Water Research Report for Mining

The project summaries in these Research Reports are 2-12 pages in length depending on the complexity of the project and are categorized into the following topic areas:

- Best Practices
- Mine Depressurization Water
- Mine Water Return

- Natural and Anthropogenic Inputs to the Athabasca
- Oil Sands Process-Affected Water (OSPW) Chemistry and Toxicity
- Pit Lakes
- Regional Water Projects
- Water Treatment

5.2.1 Best Practices

Sharing best practices between members is an excellent means of improving environmental performance of the sector quickly and cost effectively. Best practice sharing is an on-going activity in COSIA. An example of a shared best practice directly related to Oil Sands Mining Water Management Framework is the substitution of seal water flush from fresh river water to recycled OSPW in hydro-transport and tailings pumps, a good example of water re-use. These pumps are very large, and each mine lease has dozens of these pumps, so the seal water flush volume is significant. Replacing fresh water with recycled OSPW reduces the water use intensity of the mine and has been proven through use to be safe and reliable.

5.2.2 Mine Depressurization Water

Mine depressurization water (DP) is groundwater pumped from upstream of the mine faces to prevent pit flooding and mine face instability / collapse which could have serious safety and environmental impacts if not effectively managed. Mine depressurization water projects all relate to developing cost effective management / treatment technologies for highly saline DP waters. Key learnings from these projects include:

- Mining has interrupted the flow of some of these natural saline waters to the Athabasca River
- There are a number of treatment options available, but most are not cost effective and have a poor net environmental effect (2018 Water Research Report for Mining)
- Combining freeze-thaw desalination with deep-well disposal of the very saline water and release to the Athabasca River of the desalinated water has the best combination of low cost and low net environmental effect of technologies studied to date. However, the desalinated water is still toxic to some aquatic life and would require an acute toxicity mixing zone as provided for in AEP's Water Quality-Based Effluent Limits manual

5.2.3 Mine Water Release

Mine water release is an essential part of the Oil Sands Mining Water Management Framework. Mine water release projects include assessing the impacts of delayed water release on salt accumulation on site, modeling of treated mine water releases to the Athabasca River and the use of testing facilities including "pilot rivers" for assessing the impact of treated mine waters on aquatic biota. Key learnings from these projects include:

- The Athabasca River Model or ARM which has been used for regulatory applications has

been significantly improved. It can back-calculate the allowable loads (kg/day) for more than 60 compounds with some or all mining leases releasing simultaneously to ensure that the effects thresholds in the Athabasca River for these compounds are never exceeded.
- Salts will accumulate in waters, tailings deposits and soils on mine leases if treated water release is delayed to the closure landscape and result in a delay in achieving closure objectives for decades or centuries.
- Mesocosms can be an excellent means of assessing the impacts of treated mine waters on aquatic biota. In fact, one of the options assessed in the Pilot Rivers study is being deployed to test the treated waters from Syncrude's carbon filtration pilot project

5.2.4 Natural and Anthropogenic Inputs to the Athabasca River

The Athabasca River and its tributaries flow through the McMurray formation containing oil sands ore, so differentiating natural vs anthropogenic impacts in the watershed is not trivial. COSIA projects related to this topic include assessment of the bioaccessibility / bioavailability of trace elements in the region, size-resolved fractions of dust containing trace elements in snow and peatlands, water quality in the Athabasca River including impacts of delayed mixing of the Horse and Clearwater Rivers and the impact of climate change on the watershed. Key learnings from these studies include:

- Most trace elements in the dissolved fraction in the Athabasca River do not increase from upstream to downstream of the mining region
- Increases in some trace elements (TEs) from upstream to downstream of the mining region are due to delayed mixing of the Horse and Clearwater rivers which have higher salinity and carry an abundance of naturally-occurring dissolved organic matter
- Trace elements in oil sands ore are depleted relative to the Upper Continental Crust except for Mo and Re. As a result, increases of trace elements from upstream to downstream of the oil sands development area would not be expected other than the effects of the delayed mixing of the Horse and Clearwater Rivers.
- A state-of-the-art model using Hydrogeosphere by Aquanty indicates that the Athabasca watershed is likely to become wetter as a result of anthropogenic climate change. (2020 Water Research Report for Mining, page 18-20)

5.2.5 Oil Sands Process-Affected Water (OSPW) Chemistry and Toxicity

A series of projects have been undertaken to increase the available knowledge on the chemistry and toxicity of OSPW. It has been well known for decades that the ionizable dissolved organics in OSPW known as naphthenic-acid compounds which occur naturally in oil sands ore can be acutely toxic to many aquatic species if left untreated. Recent studies through COSIA include a toxicity identification evaluation to identify the dissolved organic compounds in OSPW that contribute the most toxicity, bioaccumulation of the dissolved organics, impact of dissolved organics on zebrafish and mice and development of a passive sampler test method (Biomimetic

Extraction (BE) with solid phase microextraction (SPME)) that provides a quick and repeatable assessment of OSPW toxicity due to dissolved organics. Key learnings from these studies include:

- The chemistry of OSPW is primarily the result of the chemistry in the connate water of the ore body being mined and this can vary within and between leases.
- The dissolved organics consist of thousands of compounds with relative toxicity data for "classes" of these.
- The toxic mode of action of the dissolved organics is narcosis.
- The ionizable dissolved organics (NA compounds) do not bioaccumulate.
- The BE-SPME method is a quick, effective means of measuring toxicity of the ionizable dissolved organics (NA compounds).

5.2.6 Pit Lakes

Pit lakes are used at virtually all open pit mine sites on earth and are a mining industry global best practice for reclamation and closure. Successful pit lakes support a variety of locally common terrestrial and aquatic species and are integrated into the reclaimed landscape. Oil sands mining like other open-pit mines create large mine voids that have to be filled. In addition to the pit lake project information in the water research reports for mining, Pit Lakes: A Surface Mining Perspective is available on the COSIA website. Projects related to this topic include three scales of pit lake research in the oil sands: pit lake mesocosms at the Innotech Vegreville facility, demonstration pit lakes – Suncor's Lake Miwasin and commercial-scale pit lake – Syncrude's Base Mine Lake. In addition, Teck has contributed a number of pit lake studies to COSIA from coal and hard-rock mining which can be applicable to the oil sands. Key learning from these projects include:

- Pit lakes require planning, of which several key elements can include an understanding of the surrounding hydrology, hydrogeology, and geochemistry of the materials in and around the pit.
- Adaptive management systems are used to steward pit lakes to acceptable outcomes. Pit lake mesocosms and demonstration pit lakes are an excellent means of testing out adaptive management approaches in advance of commercialization.
- Many successful examples of pit lakes exist in Canada and around the world.
- Pit lakes globally have a diverse range of end land use targets.

5.2.7 Regional Water Projects

A key aspect of the Oil Sands Mine Water Management Framework is to explore options to re-use mine waters to reduce water use intensity and minimize withdrawals from the Athabasca River. One of the earliest COSIA water projects was to study sharing water between mine leases and with the in situ oil sands sector via the Regional Water Management Initiative. A summary report on this project is available on the COSIA website under Water Research. Key learnings include:

- Generally, sharing of mine water to other mining leases or to in situ operations isn't cost effective, but some opportunities may be feasible as operators work site-wide water management strategies.
- Generally, a regional disposal system for OSPW or saline mine waters isn't feasible due to lack of disposal capacity in the mineable oil sands region
- A regional disposal system for in situ operators in the South Athabasca Oil Sands region may be both cost effective and feasible.
- A small regional water sharing system has been established between an oil sands mine and two adjacent in situ operations and serves as an example while other regional opportunities continue to be explored.

5.2.8 Water Treatment

By far the largest number of projects in the Water EPA are related to water treatment technologies. The oldest project pre-dates COSIA, an NSERC Industrial Research Chair in OSPW Organics Treatment at the University of Alberta, which is now in its second five-year term, has tested dozens of different treatment technologies and published more than 100 peer-reviewed articles. While too numerous to list, other projects include wetland treatment, biological treatment, photocatalytic oxidation and adsorption via activated carbon and other substrates. Key learnings form these projects include:

- The naphthenic acid compounds in OSPW will naturally degrade over time.
- The global Water treatment technology sector is very mature. As a result, there are multiple treatment technologies, both commercially available and in development that can effectively treat mine waters for release.
- Photocatalytic treatment methods are promising as they can be applied during active mining and in the reclamation landscape.
- Key technology selection considerations are cost and low net environmental effects including low GHG emissions and little or no waste generation.
- There is no one treatment technology that will result in the best combination of costs and net environmental effect for all oil sands mine leases. Each lease requires a thorough assessment of the best treatment option(s) for that lease.

6 Summary and Key Messages

- The oil sands mining industry must operate in a manner that keeps people and communities safe, and minimizes environmental impacts in all aspects of operations, including water management.
- The oil sands mining industry is committed to four key components of sustainable water management: shared water value; watershed management; reducing, reusing and safely releasing water; and balancing water, energy, air and land management footprints.
- Shared water value acknowledges that water is an essential foundation for life (environmental) and for our society (economic, social, and cultural);
- Watershed scale management balances water use in the context of the watershed; taking into account all users and cumulative impacts;
- Principle of reduce-reuse-return:
    - Reduction of water use balances water use reduction with the net environmental effect of these reductions;
    - Reuse of water improves water efficiency
    - Releasing treated water to the watershed that meets all environmental and regulatory requirements
- Sustainable water management must include risk analysis and understanding of trade-offs between water management, energy footprints, air quality and land management.
    - Oil sands mining companies can successfully and effectively treat oilsands mine waters and release it safely to the environment.
    - This will help in managing on-site water quantity and quality, support faster reclamation and is essential for the industry to minimize overall environmental impacts.
- Scientific research shows that the industry can safely return water to the environment.
    - More than 185 scientific articles and 50 years' worth of studies support industry's ability to safely return water to the environment.
- The oil sands mining industry is committed to scientifically rigorous, comprehensive, integrated and transparent environmental monitoring that feeds back into the process for setting responsible effluent limits
- Beyond project-specific monitoring, the industry supports and invests significantly in Alberta and the federal governments' Oil Sands Monitoring program (OSM)
- As a regulated industry, oil sands mines cannot proceed without a comprehensive Environmental Impact Assessment determining the project is in the public interest. The regulated release of treated mine water will be held to the same robust standards.
- Industry is committed to a sustainable water management framework comprising components that together make it comprehensive and adaptive.
- The development of end of pipe limits based on regional watershed management;
    - Site specific characterization of water and opportunities for water reduction,

reuse andrelease; and
    - End of pipe toxicity testing and environmental effects monitoring in the receiving environment to ensure that there are no unacceptable environmental impacts
- Oil sands mining companies take their environmental obligations and responsibilities veryseriously.
- The industry’s ongoing investments in research and development will continue to bring greater expertise, technological innovations and sound practices to manage water and reduce overall environmental impacts.