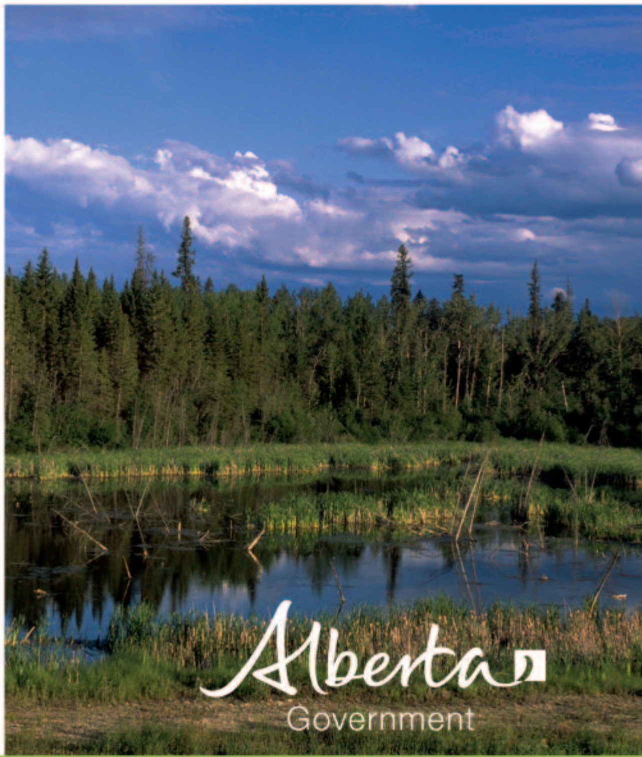
Lower Athabasca Region
Groundwater Management Framework





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1.0 Introduction

Alberta Environment and Sustainable Resource Development's three Lower Athabasca Region management frameworks were developed using input from different stakeholders within the Lower Athabasca Region including industry, First Nations and Métis peoples, and non-governmental organizations. As part of a series developed by the department for the Government of Alberta's *Lower Athabasca Regional Plan*, these frameworks are designed to maintain flexibility and to proactively manage cumulative effects to air quality, surface water quality and groundwater quality and quantity within the Lower Athabasca Region. The frameworks provide context for development and related regulatory processes, and facilitate sustainable resource management. They are intended to add to and complement, not replace existing policies, legislation, regulations and management tools.

The frameworks are policy documents that will be implemented and given legal authority as specified in the *Lower Athabasca Regional Plan*, and through Alberta Environment and Sustainable Resource Development's and potentially other departments' mandates and legislation.

The **Air Quality Management Framework** provides an additional component for the region in the overall air quality management system. This includes setting of ambient air quality triggers and limits for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) with guidance for long-term decision-making and management.

The **Surface Water Quality Management Framework** focuses on the lower Athabasca River downstream of the Grand Rapids to the Athabasca River Delta. It sets surface water quality triggers and limits for 39 indicators measured at the Old Fort monitoring station.

The goal of the **Groundwater Management Framework** is to enhance the existing system to manage non-saline groundwater resources across the Lower Athabasca Region including management of potential cumulative effects on these resources. It establishes indicators of groundwater quality and quantity and the method for developing triggers and limits. This document forms the basis for more technical, detailed documents that have been prepared for each of the groundwater management areas in the region. These are *Groundwater Management Framework* supporting documents for the:

- North Athabasca Oil Sands (NAOS) Area
- South Athabasca Oil Sands (SAOS) Area
- Cold Lake – Beaver River (CLBR) Area

There will also be a document that provides information on the preparation and submission of groundwater management plans:

- *Guidance Document for Groundwater Management Plans for In Situ Operations.*

Please note that in May 2012, the Government of Alberta brought together the ministries of Environment and Water and Sustainable Resource Development to create one ministry called Alberta Environment and Sustainable Resource Development.

2.0 Purpose

The framework described in this document is part of the shift to cumulative effects management. It seeks to balance anticipated development with environmental protection. The use of indicators of groundwater quality and quantity and regional triggers and limits helps to clearly define the management of cumulative effects of development and contributes to the achievement of desired regional objectives for groundwater quality and quantity.

This *Groundwater Management Framework* was prepared by Alberta Environment and Sustainable Resource Development for the *Lower Athabasca Regional Plan*, one of seven regional plans being advanced under the *Alberta Land Stewardship Act* and the *Land-use Framework*.

The Lower Athabasca Region is the focus of major industrial development that is driving Alberta's and Canada's economy. Increasing population and industrial expansion is expected to continue in the coming years making management frameworks important components of the regional plan.

This framework provides a system for determining sustainable management strategies for future development while ensuring protection of groundwater and any ecosystem component dependent on the interaction with groundwater. The framework provides an overall means to establish scientifically-based triggers and limits for evaluating quantity and quality of non-saline groundwater in the Lower Athabasca Region. Established interim regional groundwater quality triggers are based on data collected to date, the current level of knowledge and professional judgment, or existing provincially accepted water quality guidelines. The framework describes plans to develop final triggers and limits and a management response that will be used if triggers and limits are exceeded.

Goals of the Groundwater Management Framework

- Establish the baseline groundwater conditions and range of natural variability in the Lower Athabasca Region to facilitate enhanced knowledge and detection of change.
- Provide a consistent approach to understanding potential effects from all development activities on the surrounding environment.
- Facilitate projections of change based on future scenarios, such as expanding development or climate variability and change.
- Support and supplement the current pollution prevention and risk management principles as part of groundwater quality and quantity management.

2.1 Regional Context

The Lower Athabasca Region is a complex area with respect to groundwater resources. Variable topography, groundwater flow conditions and resulting porewater interactions have created a heterogeneous hydrogeological regime. Imprinted on this natural complexity is human development, complicating resolution of water quality and quantity issues that may be identified.

This *Groundwater Management Framework* has been developed in conjunction with supporting documents that address the unique geological and hydrogeological conditions for each of the three groundwater management areas shown in Figure 1.

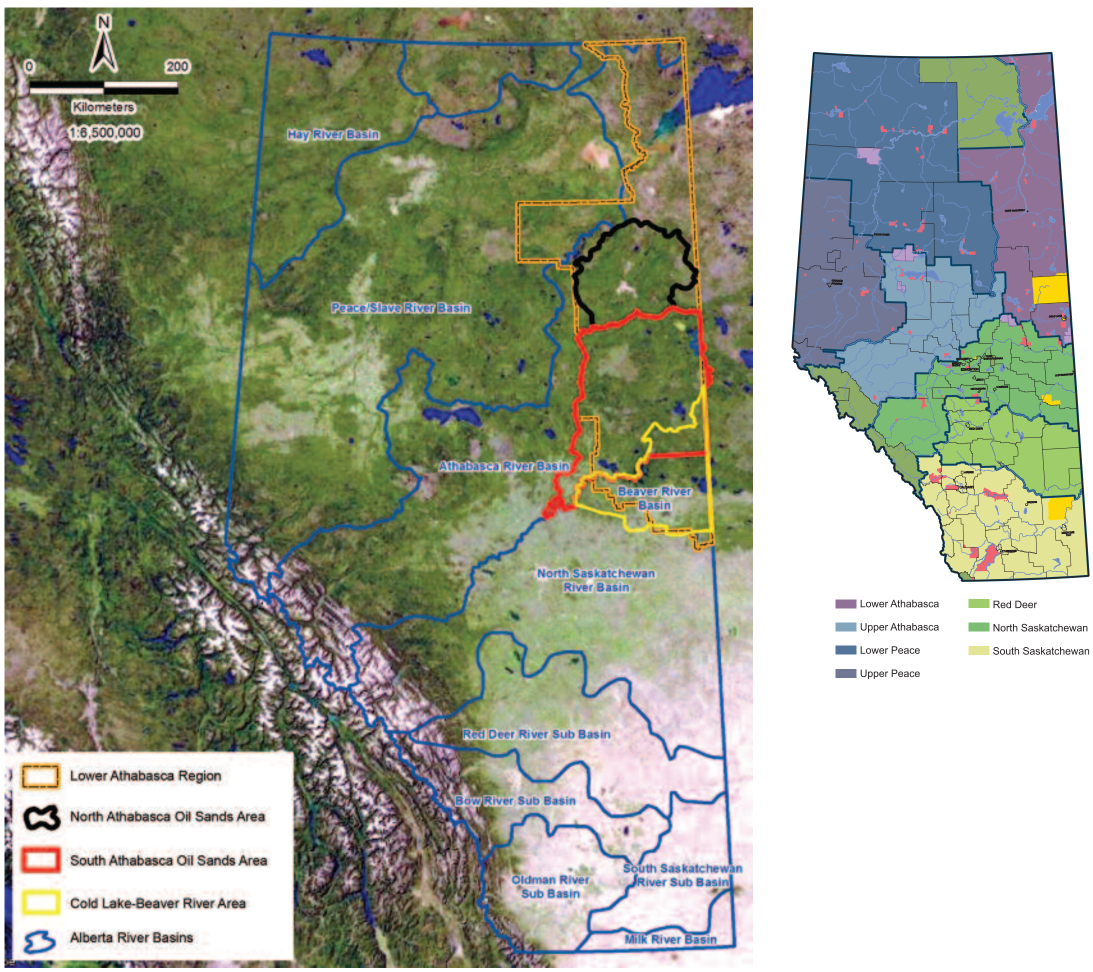

Figure 1
Map of the groundwater management areas with an accompanying map showing Alberta's seven regional plan areas

Note: The *Groundwater Management Framework* only applies within the boundary of the Lower Athabasca Region. The boundaries shown for the SAOS and CLBR areas in Figure 1 reflect the domain of numerical models that have been developed in each area.

2.2 Framework Development

The *Lower Athabasca Regional Plan* is one of seven regional plans being developed under Alberta's *Land-use Framework* (2008) to acknowledge the diversity of the regions, while coordinating provincial decisions about Crown lands and local land-use decisions.

To complete this framework as part of the regional planning process, select national and international groundwater management frameworks were considered, existing information on the region's groundwater resources was compiled and knowledge gaps were identified.

Technical experts from a number of government agencies including provincial departments and the Energy Resources Conservation Board, academics, consultants and industry representatives provided input into the framework through discussions, workshops, and written feedback. An international panel of subject matter experts from Spain, United Kingdom, United States, Australia and Canada also provided a review.

In 2010, the Government of Alberta led a public consultation process about the *Lower Athabasca Regional Plan* that involved gathering feedback on key aspects of advice provided by the Regional Advisory Council and an opportunity for contributions from the public, First Nations and Métis peoples, federal regulators, and stakeholders including industry and non-governmental groups. An engagement process led by Alberta Environment and Sustainable Resource Development involved discussions with stakeholders, First Nations and Métis peoples and considered written feedback about the framework.

All technical and editorial input from consultation and engagement was considered as the framework was developed. Overall, the comments received during the engagement and consultation processes supported the framework as a beneficial tool for groundwater management within the Lower Athabasca Region.

3.0

Key Concepts and Principles

Two drivers have guided this framework. The first is the need to build on provincial environmental protection and management policies and principles. The second is the need to adopt a cumulative effects management system in the region.

3.1 Provincial Policy Direction

One of the purposes of regional plans is to translate provincial policy to the regional scale. The *Groundwater Management Framework for the Lower Athabasca Region* helps to do that.

By reflecting the ongoing desire to balance environmental, economic and social considerations, this framework aligns with the goals of Alberta's *Land-use Framework* and other key policies including *Water for Life*.

Since 2003, *Water for Life* has been the platform for managing Alberta's water resources. In the renewed 2008 strategy, government accelerated action to safeguard Alberta's water resources and described goals for the sustainable development and management of provincial water resources – both surface water and groundwater. Groundwater is defined by the *Water Act* as all water under the surface of the ground whether in liquid or solid state.

Under the mandate of Alberta Environment and Sustainable Resource Development, the *Groundwater Management Framework* applies to water that has a mineralization of 4,000 mg/L total dissolved solids or less (referred to as non-saline water). Water that is naturally saline, which has a mineralization in excess of 4,000 mg/L total dissolved solids is outside the scope of this framework. However, if the initial mineralization is in excess of 4,000 mg/L total dissolved solids, and over time mineralization changes to below 4,000 mg/L, then this framework and provisions under the *Water Act* apply.

3.2 Cumulative Effects Management and Management Frameworks

The Government of Alberta has made a commitment to cumulative effects management that focuses on achieving outcomes; understanding the effects of multiple development pressures (existing and new); assessing risk; collaborative work with shared responsibility for action; and improved integration of economic, environmental and social considerations. It also follows an adaptive management model, which means decision-makers learn from experience and new information, and adapt to changing social expectations and demands. Performance management, along with pollution prevention principles, is essential to providing information on environmental conditions and identifying the need for any adjustments and changes on an ongoing basis. The development of management frameworks is an important addition to accomplish this shift to a cumulative effects management system. They will play an important role in long-term planning and decision making within the regional plan. The management framework approach is depicted in Figure 2.

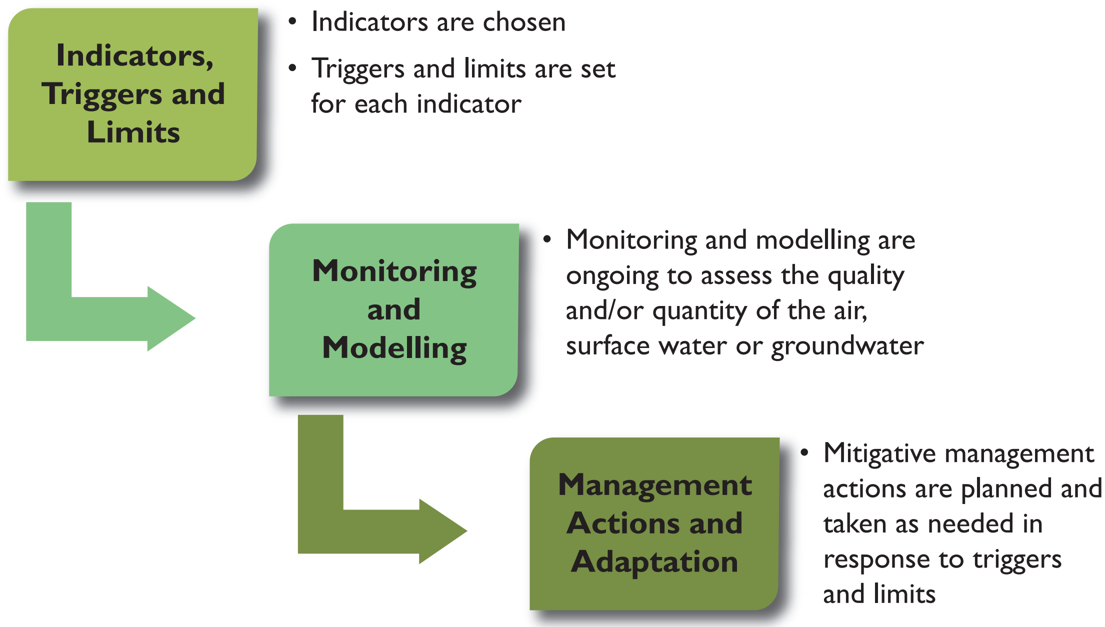

Figure 2
The Management Framework Approach

3.3 Key Principles

The following are key concepts and principles that form a foundation for the management framework.

3.3.1 Prevents Pollution

- Pollution prevention is a fundamental part of this framework. This principle, as reflected in the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (Alberta Environment 2009a and 2009b), applies across the region.
- Soil and groundwater contamination may be prevented or minimized by exercising care and control through:
  - proper locating of facilities and chemical/waste storage and management areas
  - primary and secondary containment of areas with higher potential for contaminant releases
  - regular inspections and maintenance of facility equipment, piping and containment vessels and structures
  - implementation of soil and groundwater monitoring and reporting programs
  - early identification of contaminant releases and subsequent containment, control and remediation
  - implementation of proper waste handling, disposal and management practices.

3.3.2 Identifies and Manages Risk and Adverse Trends

- There are potential risks to groundwater quality and quantity from various activities in the region. Risks may manifest within individual projects or as an aggregate of development activities. Areas where there may be risk to groundwater and connected water systems must be identified, monitored and managed.
- Continuing identification and management of risk will be part of the implementation of this framework.
- Monitoring, modelling and other tools will be used to identify and evaluate emerging trends at a local and regional scale. This emphasis on proactively understanding trends and developing triggers is especially critical in groundwater management because of the lengthy and costly process of investigating and remediating impacts.

3.3.3 Utilizes a Regional Approach

- The framework establishes a regional approach to monitoring, modelling and management, which includes regional triggers and limits. The framework requires regulated industry to participate in this regional approach.
- There will also be site-specific triggers and limits. These site-specific requirements will be identified in the *Environmental Protection and Enhancement Act* approvals and *Water Act* licences. There will also be information provided in the *Guidance Document for Groundwater Management Plans for In Situ Operations* and other materials related to regulatory requirements. Ensuring compliance with these requirements will greatly reduce the chance of a regional effect.
- When effects manifest outside of the region, the framework may extend beyond the jurisdictional boundaries of the Lower Athabasca Region.

3.3.4 Builds on Existing Regulations and Policies

- The framework is intended to add to and complement, not replace, existing policies, legislation and regulations. This includes requirements related to pollution prevention and incorporation of the best available technology economically achievable.
- The framework is consistent with provincial policies, strategies and frameworks, and with the stated desired outcomes for the region.

3.3.5 Clearly Communicates

- Under this framework, information-gathering will promote an understanding of natural variability in regional groundwater conditions. This information will be communicated by Alberta Environment and Sustainable Resource Development or its delegate in the form of fact sheet updates, an established website or other appropriate communication tools.

3.3.6 Involves Partnerships

- Citizens, communities, industry and government must share the responsibility for groundwater management. As with framework development, Alberta Environment and Sustainable Resource Development will continue to involve stakeholders, First Nations and Métis peoples, and working groups who live and work in the area as the framework is implemented.
- Groundwater monitoring and data collection is conducted by environmental and community associations and councils comprised of citizens, First Nations and Métis peoples and industry and government representatives.

4.0 The Current Management System

4.1 Regulatory and Policy Context

The use of non-saline groundwater is governed by the provincial *Water Act* and requires a licence under that legislation. In addition, industrial activities that may impact soil and groundwater quality are regulated under the *Environmental Protection and Enhancement Act*. Under the existing regulatory system, proponents or operators of industrial facilities assess the risk of potential contamination of soil and groundwater as part of environmental impact assessments and/or applications for operating approvals or their renewal. Applicants and regulators refer to several policies and guidelines in the preparation and review of proposed developments. These include the *Alberta Tier 1 and Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV 2009a and 2009b), *Water Conservation and Allocation Guideline for Oilfield Injection* (2006), and the *Alberta Environment Guide to Groundwater Authorization* (2011).

There are also major provincial policies and strategies that guide management and planning for groundwater resources and which also provided direction for this framework. The outcomes and goals in the *Water for Life* strategy have been embodied in the framework. Additional context for management of the environment in the region is provided by the *Regional Sustainable Development Strategy for the Athabasca Oil Sands Area* (1999) and *Responsible Actions: A Plan for Alberta's Oil Sands* (2009).

The management of groundwater resources within the current regulatory system will continue to be instrumental for the successful implementation of the additional components included within the *Groundwater Management Framework*. Table 1 summarizes the key policy and legislation governing groundwater.

Table 1. Key Legislation and Policy for Managing Groundwater in the Lower Athabasca Region

Governance	Jurisdiction
Provincial Acts, Regulations and Authorizations	
Alberta Land Stewardship Act (ALSA)	Provincial / Regional
Environmental Protection and Enhancement Act (EPEA)	Provincial
Water Act	Provincial
Approvals, monitoring and reporting requirements	Alberta (EPEA)
Compliance and enforcement	(EPEA and *Water Act*)
Licences, approvals, monitoring and reporting requirements	Alberta (*Water Act*)
Guidelines and Policies	
Alberta Tier 1 and Alberta Tier 2 Soil and Groundwater Remediation Guidelines (Alberta Environment 2009a and 2009b)	Alberta
Alberta Environment Guide to Groundwater Authorization (2011)	Alberta
Water Conservation and Allocation Policy for Oilfield Injection (2006)	Alberta
Guidelines for Canadian Drinking Water Quality	Health Canada
Strategies	
Land-use Framework (LUF)	Provincial / Regional
Regional Sustainable Development Strategy for the Athabasca Oil Sands Area	Alberta
Responsible Actions: A Plan for Alberta's Oil Sands	Alberta
Water for Life	Alberta
Federal Acts	
Canadian Environmental Assessment Act	Canada
Canadian Environmental Protection Act	Canada

4.2 Overview of Groundwater in the Region

The Athabasca oil sands are located in the northeastern portion of the province and extend from townships 77 to 100 and ranges 1 to 25 west of the fourth meridian. It is a vast region of predominantly mixed-wood to the south and boreal forest to the north, with little development. Exceptions include a few small to moderate-sized communities (e.g., Fort McMurray) and commercial enterprises and the more recent commercial-scale in situ projects. The oil sand deposits beneath the area represent one of the world's most prolific hydrocarbon resources and are the focus of much activity.

To address concerns about potential cumulative effects to groundwater quality and quantity from current and future development in the region, three groundwater management areas have been identified. Technical details about these areas, including descriptions of hydrogeological conditions, are provided in the groundwater management framework supporting documents.

4.2.1 The North Athabasca Oil Sands (NAOS) Area

The NAOS area encompasses approximately 18,000 square kilometers north of Fort McMurray and includes the lease areas for mineable oil sands and some in situ developments. Approximately 950 square kilometres (6 per cent) is underlain by oil sands deposits accessible from the surface using traditional strip mining techniques.

Groundwater in the NAOS area is contained within unconsolidated surficial deposits made up of sand and gravel of glacial origin, buried channel deposits of the same origin, and permeable sediments of deeper bedrock formations (marine to continental origin). The most important intervals relating to non-saline groundwater in the region include sand and gravel deposited in the:

- surficial deposits
- buried channels
- Basal McMurray Aquifer Management Unit 1
- Basal McMurray Aquifer Management Unit 2.

In some cases, intervals within the bedrock formation comprising the Grand Rapids, Clearwater and Basal McMurray formations contain non-saline water, which is included in this framework.

4.2.2 The South Athabasca Oil Sands (SAOS) Area

The SAOS area encompasses approximately 35,215 square kilometers south of Fort McMurray and includes the lease areas for in situ development. None of the oil sands deposits are accessible using surface mining techniques.

Groundwater in the SAOS area is contained within unconsolidated surficial deposits comprising a mixture of pre-glacial or glacially-derived sand and gravel aquifers. These are contained within buried channels or outwash plain deposits, and are confined by low permeability till and/or clay. Beneath the unconsolidated sediments are bedrock deposits comprised of marine shales and siltstones, and continental to marginal marine sandstones. Many of these sandstone intervals contain natural gas and hydrocarbon resources, but also host saline water supplies.

The most important intervals containing non-saline groundwater resources in this area include:

- surficial deposits
- buried channels

- Grand Rapids Formation
- Clearwater Formation
- McMurray Formation.

4.2.3 The Cold Lake – Beaver River (CLBR) Area

The CLBR area encompasses approximately 22,000 square kilometres in the Lower Athabasca Region and is commonly known as the Lakeland area of Alberta. It represents approximately 2 per cent of Alberta's surface area. Despite the relatively small size, the area has been the subject of numerous studies and investigations related to groundwater. This may be due to the unique mix of oil recovery, agriculture and residences in the area. Approximately 11.5 per cent of the bitumen in the province is mapped within this CLBR area, which accounts for 25 per cent of Alberta's current bitumen production. Bitumen production in the CLBR area is accomplished through in situ technology.

Groundwater in the CLBR area is contained within unconsolidated surficial deposits comprising a mixture of pre-glacial and glacially-derived sand and gravel aquifers contained within buried channels or outwash plain deposits and confined by low permeability till and/or clay. The major water-bearing intervals (from shallowest to deepest) include the following.

- Sand River Formation
- Ethel Lake Formation
- Bonnyville Formation sands
- Muriel Lake Formation
- Empress Formation Unit 3
- Empress Formation Unit 1.

The area is underlain by a network of buried valleys generally oriented in a west-east direction. These valleys enter and exit the CLBR area at locations independent of the present-day surface topography and drainage system and constrain distribution of the deeper formation (Muriel Lake Formation and deeper). Sediments deposited on pre-glacial valley floors include materials derived from the Rocky Mountains. These pre-glacial valleys include the Helina, Beverly, Sinclair, Wiau and Kikino.

Superimposed on the pre-glacial valleys is a series of glacially-derived channels representing ancient drainage-ways or erosional features formed during the melting of the continental glaciers. Major channels associated with this genesis include the Sand River, Bronson Lake, Big Meadow, Moore Lake and Kehiwin.

4.3 Potential Influences on Groundwater Conditions

A number of activities within the region could potentially influence groundwater quality and quantity conditions in the non-saline aquifers.

Industrial activity has been taking place in the Lower Athabasca Region for more than 40 years. At some of these sites, isolated and localized effects on groundwater quality and quantity may have occurred as a result of past industrial activities. Therefore, new facilities located on sites previously used for industrial purposes, as well as existing operations, will require efforts to protect groundwater quality and quantity.

4.3.1 Mineable Areas

Mining of the oil sands results in significant land disturbance. Large amounts of earth are removed and stockpiled to facilitate access to the mineable ore. The majority of overburden/muskeg stockpiles and tailings structures currently established are located up-gradient and some distance from potential receptors like the Athabasca River and associated tributaries. Impacts to groundwater quality tend to be localized due to the slow movement of groundwater (from less than one to tens of metres per year) and attenuating processes that occur in the subsurface. With respect to quantity, active mine areas must be de-watered for safe development; therefore, large areas of drawdown (tens of square kilometres) may develop. Changes to water quantity may affect water sources close to the surface.

The main challenges associated with mine development include:

- physical disturbance of the landscape and alteration to natural drainage and recharge patterns
- drawdown effects from de-watering of overburden aquifers and bedrock formations to facilitate safe mine development
- potential seepage of constituents from established waste containment structures
- leaching of constituents from overburden waste dumps and material stockpiles
- pressure effects and constituent migration following deep-well injection of depressurization water and process wastewater
- operational upsets (spills and leaks of chemicals and hydrocarbons at processing facilities and active mine areas).

Potential inputs to the environment from mine development include: soluble salts, dissolved organics, metals and trace elements, phenols and low molecular weight hydrocarbons.

4.3.2 In Situ Areas

There are two key types of in situ development: steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS). The primary technique is SAGD, which involves the drilling of horizontal well pairs through the overburden and confining bedrock layers into the bitumen-laden reservoir(s), followed by the injection of high temperature steam to mobilize the viscous bitumen for recovery to the surface. The CSS process is different in its application and utilizes multiple single-well completions on a dedicated production pad to pump high pressure steam into the oil sands deposits to mobilize the bitumen to the surface.

In situ activities affect water levels in various aquifer intervals primarily through the extraction and use of groundwater for steam generation to assist bitumen recovery.

There is also potential to influence quality conditions as a result of:

- physical and chemical effects from localized heating of subsurface formations
- disruption and creation of pathways to groundwater, change at connections between aquifers
- the unlikely release of production fluids from casing failures or annular leakage
- pressure effects and constituent migration from waste disposal activities
- operational upsets such as spills, leaks and uncontrolled releases of chemicals and hydrocarbons.

Potential inputs to the environment from in situ development include: soluble salts, dissolved organics, metals and trace elements, phenols and low molecular weight hydrocarbons.

It is recognized and accepted that in situ development will have local-scale effects.

4.3.3 Other Development

Additionally, both human-related and natural influences affect groundwater. Municipal development and agricultural, forestry and aggregate mining activities have the potential to release constituents to the surrounding environment or alter groundwater levels through water production and de-watering. Other impacts of human activity and natural events include:

- natural discharge of low-quality, saline waters from the bedrock formations into local water bodies or aquifers
- leaching of hydrocarbons, salts and trace elements from exposed bedrock formations and muskeg deposits into local water bodies
- leaching of hydrocarbons, salts and trace elements to the local groundwater from segments of oil sands deposited within the overburden deposits, and from buried channels eroding into underlying oil sands deposits
- leaching of pesticide and fertilizer residues into shallow aquifers
- upstream oil/gas activity (effects of gas production on the Cretaceous bedrock aquifer water levels)
- effects of natural disturbances such as forest fires and climate variability on regional groundwater levels and quality
- natural climate cycles affecting basin hydrology and groundwater levels.

Potential inputs to the environment include: municipal waste, fertilizers, pesticides, halogenated compounds, soluble salts, hydrocarbons, metals and trace elements, and dissolved organics.

When assessing regional groundwater conditions, all development activities need to be taken into consideration.

4.4 Groundwater Monitoring and Modelling

A knowledge base of groundwater conditions is essential to developing and delivering the management framework. This knowledge base relies on the use of a number of tools – monitoring, modelling and risk mapping.

The current status of monitoring and modelling efforts conducted within the Lower Athabasca Region is summarized in the table below. More information on monitoring, modelling and risk mapping is included in the supporting document for each area.

Table 2. Current Groundwater Monitoring and Modelling in the Lower Athabasca Region

Area	Monitoring Network	Model	Risk Mapping
NAOS	Existing with Expansion Underway	Complete	Complete
SAOS	Conceptual Design Stage	Complete	Complete
CLBR	Existing with Expansion Proposed	Existing – with Update Proposed	Complete

4.4.1 Monitoring

Monitoring of groundwater conditions has been occurring in the region for the last 20 to 30 years. Much of this has been associated with site-specific programs at oil sands operations (mining and in situ). Some regional groundwater monitoring was conducted through the Groundwater Observation Well Network (GOWN) from the early 1970s until the mid-1990s as part of a provincial government initiative. The scale of development at that time was limited, with only the Suncor and Syncrude base mines active, at much smaller scales than currently, and some in situ development in the Cold Lake area. Considering the limited scale of development at the time, and the location of the regional monitoring wells, the information obtained from this monitoring may in many cases be considered pre-development.

A hiatus of regional monitoring occurred between the mid-1990s until the regional monitoring network in the NAOS area was established in 2009. During this hiatus in regional monitoring, site-specific monitoring was still occurring. Regional monitoring has also been occurring in the CLBR area. At present, there is no regional-scale monitoring network in the SAOS area.

Development of a comprehensive Regional Groundwater Monitoring Network across the region is one of the commitments of this framework. Wells selected for the network include some of those monitored previously by Alberta Environment and Sustainable Resource Development so as to extend the historical records and facilitate analysis of long-term changes and trends.

The objectives of the Regional Groundwater Monitoring Network are to:

- gain a better understanding of natural variability of groundwater conditions in the region
- provide good baseline coverage (in areas of no anthropogenic effects) in each of the key regional aquifers
- gain further understanding of aquifer interactions, and how/where the groundwater system is connected to surface environments
- assess long-term water quality and water level trends, and assess potential cumulative effects from current and future development activities in the three areas.

The network will be used to assess whether changes in groundwater conditions have occurred, or are occurring, that fall outside of:

- the range of natural variability
- an acceptable condition
- the natural ability of the region to attenuate related effects.

4.4.2 Modelling

Groundwater modelling in the Lower Athabasca Region is a tool used to obtain estimates of groundwater quantity. It has been and will continue to be used to estimate volumes associated with the various regional aquifers and drawdown effects related to activity in the region. It also serves as a tool to aid in the design of the Regional Groundwater Monitoring Network. The following models have been developed.

- Initial numerical modelling of cumulative drawdown effects in the entire Lower Athabasca Region has been conducted and represents a strategic level assessment generated from regional geological and hydrogeologic information.
- A coarse grid numerical model has been constructed for the SAOS area. Initial simulation results from this model have been used to develop the conceptual groundwater monitoring network based on projected drawdown and risk potential identified by the risk mapping.

- A numerical groundwater flow model was developed by the Alberta Geological Society for the entire CLBR Region and all Tertiary/Quaternary formations. It is a regional scale model developed specifically to gain an understanding of the regional water balances and groundwater flow regimes.
- A conceptual model has been developed for the NAOS areas and has been used as the basis for the development of a numerical model. Results from this model, serve to quantify groundwater resources and will inform the establishment and expansion of the groundwater monitoring network.

A recommendation for detailed modelling of the NAOS and CLBR areas, including groundwater interaction between aquifers, groundwater-surface water interaction and quantification of groundwater has been made by the international panel that reviewed the groundwater management framework supporting documents for the oil sands areas.

Continued refinement of groundwater modelling in the NAOS, SAOS and CLBR areas will occur as information from the Regional Groundwater Monitoring Network becomes available. Integrated modelling for the region for groundwater, surface water and climate will provide a much more representative assessment of current groundwater quantity and use from the various aquifer intervals, as water withdrawal or water injection activities continue to occur and develop. Predictive modelling of cumulative effects may be used in the future to support regulatory decision making.

4.4.3 Risk Mapping and Other Studies

Initial work to identify potential areas of risk in the Lower Athabasca Region has been conducted by mapping intrinsic properties of the subsurface and overlaying current and proposed development activities that could affect groundwater resources.

A modified version of the United States Geological Survey model for mapping intrinsic vulnerability (Aller et al. 1987) was used to map the surficial sands and buried channels/valleys. This approach is a qualitative indexing method that takes into consideration the vulnerability of the subsurface to surface activities, and consists of weighted layers of information that when combined provides an overall intrinsic vulnerability score for a given location. It should be noted that vulnerability mapping is a management tool and should never be considered a replacement for on-site hydrogeological investigations.

4.5 Groundwater Quality and Quantity Conditions

Details of the evaluation used to inform the current understanding of baseline groundwater surface elevations, groundwater quality conditions, and knowledge and data gaps for certain areas and aquifers are provided in the groundwater management framework supporting documents.

4.5.1 North Athabasca Oil Sands (NAOS) Area

With respect to groundwater quality, no significant trends in key indicators have been recorded since initial sampling in 1975. Currently, there is poor to fair knowledge of groundwater quality in the surficial sands and buried channels within the NAOS area, as well as the Basal McMurray Formation. There is little to no information for the water-bearing intervals within the Clearwater, Grand Rapids and Methy Formations. According to existing data, a considerable range in physical and chemical quality exists for various indicators. This illustrates the high degree of variability throughout the NAOS area resulting from the natural hydrogeologic complexity.

Generally, groundwater types range from a relatively fresh Ca-Mg-HCO_3 to more brackish to saline Na-HCO_3 to Na-Cl types. Mineralization for porewaters in the surficial deposits, including surficial sands and buried channels, is typically less than 1,000 mg/L total dissolved solids (TDS). For the shallower bedrock aquifers, TDS values range from non-saline up to saline (1,000 to 4,000 mg/L), with the deeper formations (Basal McMurray and Methy formations) generally indicating saline to brine conditions (4,000 to greater than 300,000 mg/L TDS). As indicated previously, groundwater having a mineralization of 4,000 mg/L TDS or greater falls outside the jurisdiction of this framework.

Chemistry data for the Basal McMurray Formation varies significantly on a spatial basis. This has led to the proposed creation of Aquifer Management Units within this interval. The definition of these Aquifer Management Units facilitates management of the groundwater quality and quantity resources at an appropriate scale. Similar conditions exist for the Methy Formation in locations situated near outcropping areas to the north and east; however, not enough information exists at present to warrant the development of Aquifer Management Units for this, or other, deep water-bearing intervals. Significant variability in TDS values has not been noted in other shallower bedrock or unconsolidated formations, with the possible exception of intervals near the Athabasca River, therefore, Aquifer Management Units have not been proposed thus far.

As for water levels, wells completed in the surficial deposits and channels have shown fluctuations consistent with natural seasonal, intra-decadal and inter-decadal variability. Evidence of drawdown in the Basal McMurray aquifer (on the order of 15 to 25 m) exists at monitoring wells established near active mining areas. This is to be expected as de-watering of the Basal McMurray is occurring for safe mine development. All other wells have shown trends consistent with natural variability or slow recovery towards static following installation or subsequent to purging events.

Initial high-level estimates of groundwater volumes and recharge in the Lower Athabasca Region suggest a significant and sufficient volume to accommodate the current level of development and water use (WorleyParsons 2010b). However, additional data is required from future monitoring and assessment initiatives to refine these estimates and help facilitate future determination of sustainable yields for the regional aquifers in the NAOS area. Changes due to alteration of the landscape and climate variability (i.e., the balance between precipitation and evaporation/evapotranspiration rates) also factor in as they affect recharge to the system and associated storage volumes.

4.5.2 South Athabasca Oil Sands (SAOS) Area

At present, information pertaining to groundwater quality conditions in the various key aquifers beneath the SAOS area is limited both from a temporal and spatial perspective. As such, the expectation going forward is that knowledge of baseline conditions and ranges of natural variability will become further defined through continued monitoring at established operations, baseline monitoring at newly proposed projects, and through the development of a regional-scale monitoring network.

Spatial and temporal groundwater chemistry data available for these aquifer intervals has been assessed to generally characterize baseline groundwater quality and to identify gaps in data and the regional knowledge base. Groundwater chemistry data was accessed with the majority of information obtained from the southwest area, with lesser amounts provided from the rest of the SAOS. Some general patterns of groundwater quality are evident from a review of spatial distribution of TDS and other related parameters. As with the NAOS area, there is a high degree of groundwater quality variability within these aquifers. Some examples are:

- The surficial deposits (of glacial and pre-glacial origin) display a wide variability of water types ranging from fresh Ca-Mg-HCO_3 water to older Na-HCO_3 and Na-Cl dominated waters. These characteristics are representative of groundwater within recharge and discharge stages of local to intermediate flow systems, respectively.
- The Empress and Grand Rapids aquifers commonly show similar hydrochemical signatures. Both intervals tend to possess TDS concentrations fresher than the deeper Clearwater and McMurray aquifers indicating less residence time of the associated porewater.
- The Clearwater and McMurray aquifers tend to be dominated by brackish to saline Na-Cl type waters indicating a comparatively longer residence time and indicative of larger-scale regional flow systems.

Given the highly clustered nature of the data, it is difficult to properly frame the regional context of groundwater conditions in the SAOS area. Further information provided by local-scale and regional-scale monitoring initiatives will help resolve this challenge.

Individual oil sands operators have designed and implemented groundwater monitoring programs on their leases pursuant to the terms and conditions of their *Water Act* licences and the *Environmental Protection and Enhancement Act* approvals.

In terms of quantity, based on the modeled projections of current pumping and injection in the SAOS area to 2030, it does not appear that the 50 per cent drawdown guideline, from the *Water Conservation and Allocation Guideline for Oilfield Injection*, would be exceeded anywhere in the SAOS area. Some current projections note a maximum future drawdown of 35 per cent for the Lower Grand Rapids; about 25 per cent for Clearwater A; about 15 per cent for Clearwater B; and five per cent for the McMurray Basal Sands where injection adds to the available head.

4.5.3 The Cold Lake − Beaver River (CLBR) Area

Key aquifers for the CLBR area have been identified based on the availability of geological and hydrogeological information, priority of water use and deep well waste-disposal activities. A comprehensive evaluation of groundwater quality data in the CLBR area was completed, and preliminary baseline conditions have been tied to a comprehensive conceptual geological model of the Quaternary and Tertiary deposits in the region. Some general patterns of groundwater quality are evident from a review of the spatial distribution of mineralization and other related parameters. There is not as high a degree of variability of water quality within the aquifers of the CLBR area as there is in the NAOS and SAOS areas.

Groundwater in the CLBR area ranges from a relatively fresh Ca-Mg-HCO_3 type in the near-surface intervals, to a more brackish Na-HCO_3 type increasing with depth. The regional groundwater chemical quality generally falls within current *Guidelines for Canadian Drinking Water Quality* (Health Canada 2008), and has not changed detectably over time. This finding is based on two decades of data collected for the region. However, groundwater quality at particular locations in the region may not meet the drinking water guidelines due to naturally occurring substances such as arsenic and uranium. Arsenic and uranium concentrations are often naturally elevated in certain formations (Bonnyville, Muriel Lake and Empress Unit 3) as a result of the geochemical setting and mineral composition of the host sediments.

Water level monitoring has shown some effects from groundwater use in support of thermal in situ activities (primarily during the drought conditions prevailing in the 1990s); however, levels have recovered to near pre-pumping conditions since this period of sustained pumping.

5.0

Regional Objectives

In support of desired regional outcomes, this management framework establishes the following regional objectives for groundwater.

>>

Quality
Groundwater quality is protected from contamination by maintaining conditions within the range of natural variability and not exceeding established limits.

Quantity
Groundwater resources continue to support human and ecosystem needs, and the integrity of the regional flow system is maintained.

5.1 Indicators

Indicators provide information about whether or not a regional objective is being met. Aquifers beneath the Lower Athabasca Region have the potential to become affected by resource extraction development and other activities such as municipal development, forestry activity, agriculture and aggregate mining. Indicators allow Alberta Environment and Sustainable Resource Development to assess and track any changes to the groundwater resources in the region.

5.1.1 Selecting Indicators

With respect to groundwater, measurement and tracking of indicator trends helps to ensure that quality and quantity conditions are maintained for human and ecosystem needs, now and into the future. Indicator selection for groundwater quality considered current understanding of baseline conditions and parameters of concern associated with mining and in situ activities and other influences for each area. Indicators associated with mining operations were selected by reviewing descriptive statistics for parameters associated with process-affected mine waters, consolidated tailings samples, and mature fine tailings samples. For in situ operations, indicators were identified as those with potential for mobilization from sediments due to localized heating from well operations and from casing failures or annular pathways.

Tables 3, 4, and 5 summarize the various primary, secondary and tertiary indicators associated with mining operations, in situ development and other influences (human and natural). Primary indicators have been selected as the initial screening tool and include such parameters as sodium, chloride and sulphate, various trace elements and certain dissolved organics (e.g., naphthenic acids). Secondary indicators are intended to support any follow-up investigation required following the exceedance of an established trigger or identification of an unacceptable trend. If required, a tertiary level of assessment may be implemented. Tertiary indicators tend to be more sophisticated but assess conditions from a very high level of refinement. Secondary and tertiary indicators will only be used if required in subsequent phases of investigation.

Table 3. Indicators for Mining Operations

Quality	Primary	pH, redox, total dissolved solids, sodium, chloride, arsenic, ammonia, naphthenic acids.
	Secondary	All other major ions + remaining trace elements, fluoride, dissolved organic carbon, BTEX, phenols, LMW PAHs.
	Tertiary	GC-MS, stable or radiogenic isotopes.
Quantity	Primary	Temporal change in groundwater surface elevation in an aquifer management unit at an established monitoring location.
	Secondary	Impact to sensitive water body or wetland as demonstrated by water level changes. Accuracy of modeled versus measured conditions in established monitoring wells.

Table 4. Indicators for In Situ Operations

Quality	Primary	Temperature, redox, total dissolved solids, chloride, silica, arsenic, boron, phenols.
	Secondary	All other major ions + remaining trace elements, naphthenic acids BTEX, PHC F1 and F2, LMW PAHs.
	Tertiary	GC-MS, stable or radiogenic isotopes.
Quantity	Primary	Temporal change in groundwater surface elevation in a regional aquifer at an established monitoring location.
	Secondary	Impact to sensitive water body or wetland as demonstrated by water level changes. Accuracy of modeled versus measured conditions at established monitoring wells.

Table 5. Indicators for Other Influences

Quality	Primary	pH, TDS, chloride, nitrate, BTEX.
	Secondary	All other major ions, trace elements, pesticides, low molecular weight PAHs.
	Tertiary	GC-MS, stable or radiogenic isotopes.
Quantity	Primary	Temporal change in groundwater surface elevation in an aquifer management unit at an established monitoring location.
	Secondary	Measureable impact to sensitive water body or wetland as demonstrated by water level changes. Accuracy of modeled predictions versus measured conditions at established monitoring wells.

BTEX – benzene, toluene, ethylbenzene and xylenes (volatile organic compounds)
GC-MS- gas chromatography-mass spectroscopy
LMW PAHs – low molecular weight polycyclic aromatic hydrocarbons
PAHs – polycyclic aromatic hydrocarbons
pH – a measure of how acid or basic a substance is
PHC F1 and F2 – Petroleum Hydrocarbons Fractions 1 and 2
TDS – total dissolved solids
redox - REDuction-OXidation

5.1.2 Defining Aquifer Management Units

An aquifer classification scheme has been developed and is used to prioritize the management of key regional aquifers. It assists with the identification of Aquifer Management Units. This will add to the knowledge base about groundwater resources and the natural variability of existing conditions in the region. The classification of aquifers helps focus groundwater management priorities for the region and facilitates more detailed monitoring or modelling efforts in areas lacking vital information.

Using this approach, a number of aquifers have been identified as having a higher priority with respect to protection. Although this is preliminary, further refinement of this approach and its application will be possible as more data comes in from regional monitoring efforts.

5.2 Setting Triggers and Limits

Both site-specific and regional groundwater triggers and limits will be established. Site-specific triggers and limits for quality and quantity will be developed through the preparation and submission of groundwater management plans by regulated operators. The key objective of a groundwater management plan is to prevent negative effects to groundwater and surface water quality by managing, at the local scale, interactions between development activity and the environment. By ensuring proper administration of a groundwater management plan, the potential for regional cumulative effects will be minimized or eliminated in some cases. Information on the requirements for preparation of a groundwater management plan will be provided in the *Guidance Document for Groundwater Management Plans for In Situ Operations* and other materials related to regulatory requirements. The site-specific triggers and limits will be implemented through the regulatory system; further discussion of triggers and limits in this framework refers to regional values.

Regional triggers serve as early warnings of a negative change in condition from natural variability in aquifer conditions. Regional limits represent a condition beyond which the potential for impacts is considered unacceptable. A Regional Groundwater Monitoring Network will be implemented and maintained as part of the management system to provide assurance that cumulative effects are not occurring or are appropriately addressed. It will be used to establish regional triggers and limits for the regional aquifers in each of the three groundwater management areas using data collected at new and existing monitoring locations.

In the absence of a complete data set from a fully established groundwater monitoring network, interim triggers have been set for groundwater quality using the methods described in the following section. Given the current understanding of the region's complex hydrogeology, it is too early in the process to establish numerical limits. As such, an approach to setting limits will be developed in the future to meet the goals of this framework. The methodologies that will be used in the establishment of the final regional triggers and limits will be confirmed as the process to complete the management framework continues. Information on proposed methodologies is included in the groundwater management framework supporting documents.

5.3 Interim Regional Triggers

It must be recognized that knowledge of the region's groundwater resources is incomplete and continues to develop. As such, interim regional triggers for groundwater quality have been developed and are referenced in the *Lower Athabasca Regional Plan*. The interim regional triggers will be compared to measurements taken at monitoring wells identified as representative of regional quality (i.e., not to compliance wells on industrial sites) in each of the specific areas. The interim triggers will inform the identification of priorities for continuing work under the framework until sufficient data is collected to develop final triggers and limits for the indicators described previously.

Quality

Interim regional triggers were established for key aquifers and Aquifer Management Units (AMU's) based on the data collected to date, regional knowledge and professional judgment, or existing provincially accepted water quality guidelines where applicable. Descriptive statistics were generated for primary groundwater quality indicators for key aquifers; however this data did not fully represent the spatial variability of groundwater conditions. This is evident from an example taken from one of the water-bearing intervals (Basal McMurray Formation) where groundwater mineralization was found to range from less than 600 mg/L to greater that 350,000 mg/L. Given this degree of variability, even in one formation, it was difficult to define a suitable trigger to encompass all locations. Where sufficient data exists, AMU's have been defined within specific intervals to address regional variability. Until more data is collected for the regional aquifers and AMU's within each specific area, the triggers are interim in nature and subject to refinement (up or down).

The interim regional triggers for groundwater quality indicators for the NAOS area are summarized in Table 6. These values represent the 75th percentile for each identified aquifer interval as derived from the existing database of water quality except where there was insufficient data. In those cases, the interim regional trigger is based on regional knowledge and professional judgment.

The interim regional triggers for groundwater quality indicators for the SAOS area are summarized in Table 7. The interim regional trigger for arsenic represents the 75th percentile for each identified aquifer interval as derived from the existing database. The rest of the values are based on regional knowledge and professional judgment.

Table 8 contains the interim regional triggers for groundwater quality indicators for the CLBR area. The values used for total dissolved solids and arsenic are from the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2010). The remaining interim regional trigger values represent the 95th percentile for each identified aquifer interval as derived from the existing database except where there was insufficient data. In these cases the value is based on regional knowledge and professional judgment.

Quantity

At the current time, there are no interim regional quantity triggers. In their absence, a guideline exists for the in situ industry with respect to the amount of water that can be safely used in support of bitumen recovery or injection for enhanced oil recovery. The *Water Conservation and Allocation Guideline for Oilfield Injection* (AENV 2006) regulates as follows.

An applicant that proposes to use non-saline groundwater for underground (oilfield) injection will be restricted to a maximum of one-half of the long-term yield of a given aquifer in the immediate vicinity of the water source well. This will be accomplished by limiting drawdown in the production aquifer, as measured in an observation well at a distance of 150 metres from the production well, to 35 per cent during the first year of operation and no more than 50 per cent over the life of the project.

Table 6. Interim Regional Groundwater Quality Triggers for the North Athabasca Oil Sands Area (Concentrations are shown in mg/L)

Interval	TDS[1,3]	Na[1,4]	Cl[1,4]	SO_4[1]	TAN[1,3]	As[1]	Si[3]	NAs[1,3]
Surficial deposits	600[1]	50[1]	20[1]	50	1[1]	0.003	10	2[1]
Buried channels	1,000[1]	150[1]	50[1]	250	1[3]	0.003	10	3[3]
Basal McMurray AMU1	1,000[3]	200[4]	250[4]	400	2[3]	0.003	10	5[1]
Basal McMurray AMU2	3,700[3]	1,000[1]	1,100[1]	400	2[3]	0.003	10	20[1]

Table 7. Interim Regional Groundwater Quality Triggers for the South Athabasca Oil Sands Area (Concentrations are shown in mg/L)

Interval	Temperature Change[3]	TDS[3]	Cl[3]	NO_3[3]	As[1]	Si[3]	B[3]	BTEX[3]	Phenols[3]
Surficial deposits	5°C	600	50	0.05	0.003	10	0.2	<10 % DF	0.005
Buried channels	2°C	1,000	100	0.01	0.003	10	0.4	<10 % DF	0.005
Grand Rapids Formation	2°C	2,000	1,000	0.01	0.003	10	1.0	<10 % DF	0.010
Clearwater Formation	2°C	3,500	1,000	0.01	0.003	10	1.5	<10 % DF	0.010
McMurray Formation	2°C	3,500	1,500	0.01	0.003	10	2.0	<10 % DF	0.010

Note: the Grand Rapids, Clearwater and McMurray Aquifers are saline in some of the SAOS areas.

Table 8. Interim Regional Groundwater Quality Triggers for the Cold Lake - Beaver River Area (Concentration are shown in mg/L)

Interval	Temperature Change[3]	TDS[4]	Cl[2]	NO_3 as N[2]	TAN[3]	As[4]	Phenols[2,3]	PHC F1[2,3]
Sand River Formation	2°C	500	25	2.0	1	0.010	0.009[2]	0.2[2]
Ethel Lake Formation	2°C	500	25	0.5	1	0.010	0.009[3]	0.2[3]
Bonnyville Formation Sand 1	2°C	500	125	0.2	1	0.010	0.009[2]	0.4[2]
Muriel Lake Formation	2°C	500	125	0.2	1	0.010	0.009[2]	0.4[2]
Empress Formation Unit 3	2°C	500	200	0.1	1	0.010	0.006[2]	0.4[2]
Empress Formation Unit 1	2°C	500	100	0.1	1	0.010	0.004[2]	0.4[2]

1 Value represents the 75th percentile of data from the existing database for each identified interval.
2 Value represents the 95th percentile of data from the existing database for each identified interval.
3 Values selected based on regional knowledge and professional judgment.
4 Value is from the *Guidelines for Canadian Drinking Water Quality* (Health Canada 2010).
5 Values in Tables 6, 7, and 8 are interim in nature and subject to refinement based on results generated by regional groundwater monitoring.

Concentrations are shown in mg/L
AMU = aquifer management unit
TDS = total dissolved solids
Na = sodium
Cl = chloride
SO_4 = sulphate
As = arsenic
TAN = Total Ammonia Nitrogen
Si = silica
NAs = naphthenic acids
B = boron
NO_3 = nitrate
BTEX = benzene, toluene, ethylbenzene and total xylenes
DF = detection frequency
PHC F1 = petroleum hydrocarbons (fraction I)
N = nitrogen

6.0 The Management System

This framework will bring the following new elements to the existing system:

- establishment of regional objectives for groundwater quality and quantity
- identification of key indicators for those objectives
- plans to set triggers and limits for those indicators
- identification of a management response that will be initiated if triggers and limits are exceeded

This will be supported by the following enhanced management tools:

- a comprehensive Regional Groundwater Monitoring Network (with monitoring in each of the NAOS, SAOS, and CLBR areas)
- risk mapping
- modelling for the entire Lower Athabasca Region
- designation of Aquifer Management Units

The regional groundwater quantity and quality triggers to be established through this framework are associated with investigative steps and management actions. Implementation of the appropriate management actions will prevent environmental impacts, potential cumulative effects and reduce stresses on groundwater resources. Ongoing monitoring and management are required, including adjustments to the framework as necessary. As new groundwater quality and quantity knowledge is generated in the region, models will be updated and management directions will be adapted accordingly. The framework is therefore considered to be a living document and will be updated as required, with a focus on the regional triggers and limits. Alberta Environment and Sustainable Resource Development will review and update the framework to ensure alignment with other policies that are developed or revised at a regional, provincial or national level, or at a minimum 10-year interval to align with regional planning.

Elements from the framework will be included in the *Lower Athabasca Regional Plan* and will be implemented as part of that plan with legal force as provided by the *Alberta Land Stewardship Act*. The interim regional triggers are referenced in the regional plan. While interim regional triggers have been developed, a management response will not be a mandatory requirement of the regional plan until there is a better understanding of the current state of groundwater in the region and final triggers and limits have been established. Once these numbers are final, however, if monitoring indicates that a trigger or limit has been exceeded, there will be a management response initiated. Until that time, the interim triggers will inform the identification of priority areas for continuing work under the framework.

6.1 Management Response

The terms management response and management action have distinct meanings in the context of this management framework. The management response is a set of steps that will be undertaken (all or in part) if a regional groundwater quality or quantity trigger or limit is believed to have been exceeded. Part of the management response is determining the need for management actions.

Once regional triggers and limits have been established, the data from the Regional Groundwater Monitoring Network will be compared and evaluated against those triggers and limits. If a trigger or limit is exceeded, a management response will be initiated. Alberta Environment and Sustainable Resource Development recognizes that there is a potential for natural anomalies to exist and be identified through monitoring. Such anomalies will be addressed as part of the steps in the management response.

Evaluation of conditions and determination of any need for management action will also rely on trend analysis to determine if there are trends falling outside of natural variability. Identified trends will be investigated, reported, and if necessary, mitigated. The intent of investigation is to identify the source of the problem as well as natural areas of exception for the region with the ultimate goal to stabilize or reverse adverse situations. Therefore, addressing of adverse trends in water quality or quantity indicators is a fundamental part of achieving the regional outcomes.

To indicate potentially significant trends, results are analyzed according to suitable statistical tests. A suitable approach to these tests is described in the groundwater management framework supporting documents.

It should be noted that this management response does not replace other responses that are taken as part of ensuring compliance under the environmental regulatory system.

Figure 3 describes the steps in the management response.

Verification

- Verify the indicator exceedance by reviewing the data collection method and possibly re-sampling

Preliminary Assessment

- An initial evaluation of the results is completed
- If the situation is acceptable, monitoring continues
- If the situation is unacceptable, an investigation begins

Investigation

- Phase 1: If the issue is a natural aberration, then the result is documented and the area characterization is updated
- Phase 2: If the issue is human related, then further investigation begins

Mitigative Management Actions

- If the result of Phase 2 shows stabilization or reversal of unacceptable trends area characterization is updated
- If further steps are needed, then mitigative management actions are identified

Oversight/ Delivery of Management Actions

- Identify appropriate parties to be involved in development and implementation of mitigative management actions
- Select appropriate tools to facilitate implementation of management actions

Evaluation

- Evaluate results of implementation
- Continue monitoring to verify expected results

Communication

- Report on progress toward achieving framework objectives

Figure 3
Management Response

6.1.1 Verification

The initial step in the management response is **verification** of the result or measurement. This process begins with a check on integrity of the measurement, including a review of data collection procedures and well integrity. In the case of a quality parameter measurement, the laboratory may be contacted to verify sample results, which could include a re-run of the sample for a particular analysis. If the sample hold time has been exceeded or the sample has been discarded, then the well is usually re-sampled and re-submitted for analysis. If the value is found to fall within the historical range for that parameter, or an acceptable variability based on the regional context, the new value is honoured, the previous value is discarded or flagged as anomalous, the investigation is documented and routine monitoring continues.

6.1.2 Preliminary Assessment

If the original data point is found to be correct, then a **preliminary assessment** of results is conducted and an initial evaluation is completed. If the situation is deemed acceptable by regulating authorities, the result is documented and regular monitoring is continued. If results of the preliminary evaluation are deemed unsatisfactory to the review team, a more defined investigation phase is initiated to identify the origin or source of the issue.

6.1.3 Investigation

Investigation is conducted in a phased manner so that all applicable information is accessed and utilized. This includes identifying knowledge and/or data gaps and completing additional characterization work to fill the gaps and bring the issue into proper context. The goal of the review process is to ensure that any potential effects linked to the indicator change are properly assessed in order to reduce or eliminate any associated consequences. This is achieved by providing essential information for the decision-making process.

If the initial **Phase 1** investigation identifies the issue as being a naturally occurring anomaly of the system, then the result is documented and the area characterization is updated. This may lead to revision of a trigger or identification of an area as a natural exception to the regional setting. If, however, the results indicate a human-related influence, then a **Phase 2** investigation is required to assess the results against the defined outcomes for that indicator. This may include supplementary characterization using more sophisticated measurement techniques, completing risk assessment activities, and/or using predictive modelling to assess potential future effects. The results of the Phase 2 investigation may indicate stabilization or reversal of unacceptable trends, requiring only that the characterization of the area needs to be updated and regional monitoring continued, but no further action is needed.

6.1.4 Mitigative Management Actions

If results of the Phase 2 investigation confirm that there is an influence likely associated with human activities and further action is needed, then a **mitigation** phase is initiated to identify the operation(s) responsible and the kind of management actions required. At this stage, options for engineered controls, risk-based approaches or modification of operations are assessed. If the desired outcome is achieved by the mitigation measures put in place, the event is closed. If not, supplemental mitigation and assessment is required until the defined outcome is achieved. The time between mitigation and closure can be lengthy, and predictive modelling can be quite useful in determining this time frame. A period of post-closure monitoring will be required to verify model results and provide the comfort necessary to close the event.

6.1.5 Oversight/ Delivery of Management Actions

Appropriate parties to be involved in the development and implementation of management actions will be identified. There will be shared responsibility amongst these parties to make sure the actions are taken. Alberta Environment and Sustainable Resource Development will have two roles. This includes ensuring that any required regulatory or management changes are implemented and providing oversight for actions taken by other parties. Management actions may require amendments to existing approvals. Such amendments would be in made accordance with the existing authority under the *Environmental Protection and Enhancement Act* (EPEA) and the *Water Act* including Director-initiated amendments for monitoring or reporting requirements or those arising from unforeseeable effects. Alberta Environment and Sustainable Resource Development will rely on a range of EPEA and *Water Act* tools to initiate management actions where necessary.

6.1.6 Evaluation

Data collected from the Regional Groundwater Monitoring Network is intended to be evaluated and communicated on a regular basis. Specific timing will be determined by Alberta Environment and Sustainable Resource Development.

6.1.7 Communication

At present, a reporting and communication strategy has not been established for results generated by regional groundwater monitoring efforts.

As noted previously, the goal of the framework is to collect information at an adequate frequency, and for an adequate number of parameters, to gain further understanding of natural variability in regional groundwater conditions and put site-specific activities and monitoring initiatives into proper regional context. Additionally, the intent is for Alberta Environment and Sustainable Resource Development or its delegate to communicate progress reports and interpreted results in a way that is understandable. This may take the form of fact sheet updates, an established website or other appropriate communication tools.

7.0 Implementation

Over the last three years, components that support cumulative effects management have been implemented in the Lower Athabasca Region for groundwater management, including monitoring and modelling. The current management approach has therefore been evolving for a number of years, and implementation of this framework will advance it further.

Implementation details, including timelines and allocation of resources, will be determined when the *Lower Athabasca Regional Plan* has been approved by Cabinet and this framework is considered final. Implementation planning will include:

- An inventory of tasks to meet the requirements of the framework including, at a minimum, identification and development of system components such as monitoring, evaluation and reporting mechanisms; protocols for assessment of conditions relative to objectives; management response expectations; and reporting processes and communication plans for groundwater quality and quantity and management actions activated by the framework.
- Confirmation of roles and responsibilities of various groups (Alberta Environment and Sustainable Resource Development, First Nations and Métis, Watershed Planning and Advisory Councils, and other stakeholders) for implementation of the framework and an assessment of resources needed to fulfill the tasks and commitments of the framework, including human resources and any missing data requirements.
- Ongoing evaluation of the framework's alignment with other policies and initiatives (national programs, provincial policies) to ensure consistency of management intent.
- A timeline for implementation including key milestones and target dates for completion.

Other major considerations are the requirement for groundwater management plans and the possible establishment of a Groundwater Working Group.

7.1 Groundwater Management Plans

Each facility operator will be required to develop a groundwater management plan with unique site-specific indicators, triggers and limits and a suitable monitoring network to satisfy the requirements of EPEA, the *Water Act* and this framework. Alberta Environment and Sustainable Resource Development will advise facility operators of their requirements for submission of a groundwater management plan and will follow-up with any Director-initiated approval amendments if necessary. For existing facilities, within one year of the notification from Alberta Environment and Sustainable Resource Development, the approval holder in the region will be required to develop and submit a groundwater management plan for Alberta Environment and Sustainable Resource Development's review and approval. For proposed new facilities, it is expected that the elements of the groundwater management plan will be developed and submitted with their regulatory approval applications. The groundwater management plan must address the requirements identified in the

Environmental Protection and Enhancement Act approvals and *Water Act* licences. There will also be information provided in the *Guidance Document for Groundwater Management Plans for In Situ Operations* and other materials related to regulatory requirements.

7.2 The Groundwater Working Group

Establishment of a Groundwater Working Group is being considered. It could include representatives from Alberta Environment and Sustainable Resource Development, Alberta Energy Resources Conservation Board, industry, other stakeholders, First Nations and Métis, selected academics and consultants. The goal of the group would be to support establishment of the Regional Groundwater Monitoring Network and development of appropriate triggers and limits for regional groundwater quantity and quality.

8.0 Integration

The vision of this framework is to be fully integrated with a comprehensive approach to monitoring, modelling and management. The interaction between groundwater and surface water resources has been considered in the methodologies for setting triggers and limits included in the management framework. It is also intended to manage the multiple environmental stressors in the region.

Implementation of the *Groundwater Management Framework* and the *Surface Water Quality Management Framework* will improve understanding of these components of our environment and the interaction of impacts on both. As the regional plan is implemented, all of the outcomes and objectives in it, including those for surface water and groundwater, will be considered in planning and decision-making by provincial departments and municipal governments. This will help to drive integration across environmental media.

9.0 Terminology

9.1 Abbreviations and Acronyms

Abbreviation/Acronym	Description
AMU	Aquifer management unit
Ca	Calcium
Cl	Chloride
CLBR	Cold Lake – Beaver River
CSS	Cyclic steam stimulation
ERCB	Alberta Energy Resources Conservation Board
EPEA	*Environmental Protection and Enhancement Act*
HCO_3	Bicarbonate
m	Metre
Mg	Magnesium
mg/L	Milligrams per litre
Na	Sodium
NAOS	north Athabasca oil sands
SAGD	Steam assisted gravity drainage
SAOS	south Athabasca oil sands
TDS	Total dissolved solids
WPACs	Watershed Planning and Advisory Councils

9.2 Glossary

Aquifer .... An underground water-bearing formation that is capable of yielding water (*Water Act* 2009)

Aquifer management unit .... A hydraulically-connected groundwater system that is defined to facilitate management of the groundwater resources (quality and quantity) at an appropriate scale.

Basal aquifer .... The interval of McMurray Formation that is lean of bitumen and predominantly water-saturated.

Bedrock aquifer .... A bedrock formation that has the ability to transmit significant volumes of water to a well completed within it. Typical examples include sandstone and siltstone or significantly fractured intervals.

Bitumen .... A highly viscous, tarry, black hydrocarbon material having an API gravity of about nine (specific gravity about 1.0 g/cm^3). It is a complex mixture of organic compounds. Carbon accounts for 80 to 85 per cent of the elemental composition, hydrogen 10 per cent, and sulphur 5 per cent with nitrogen, oxygen and trace elements forming the remainder.

Buried valley .... An eroded depression in the soil or bedrock within which sediments significant permeability (e.g., sand) or low permeability (e.g., till, clay) accumulate.

Channel .... An eroded depression in the soil or bedrock surface within which alluvial deposits accumulate (i.e., gravel, sands, silt, clay).

Contaminant .... A substance that is present in an environmental medium in excess of natural baseline concentration.

De-watering .... Removal of groundwater from geological formation using wells or drainage ditch system.

Infiltration .... The flow or movement of precipitation or surface water through the ground surface into the subsurface. Infiltration is the main factor in recharge of groundwater reserves.

Mineralization of Groundwater .... Synonymous with total dissolved solids (typically reported in mg/L).

Naphthenic acids.......................Naturally occurring hydrocarbons found in surface and groundwater in the Athabasca Oil Sands area. Primary group of compounds toxic to aquatic organisms in oil sands process-affected water.

Permeability ....A physical property of the porous medium. Has dimensions $Length^2$. When measured in cm^2, the value of permeability is very small, therefore more practical units are commonly used - darcy (D) or millidarcy (mD). One darcy is equivalent to 9.86923×10^{-9} cm^2.

Phenols..Oxygen–substituted benzenes commonly derived from the degradation of natural organic matter, the distillation of wood and coal, and the refining of oil. This particular class of organic compounds is ubiquitous in nature, and is common in groundwater.

Polycyclic Aromatic Hydrocarbons (PAH)..................A group of over 100 different organic compounds composed of several benzene rings.

Process-Affected Water.........Any water that has come in contact with oil sands through an industrial process, and may contain hydrocarbons and other chemicals.

Recharge ....The infiltration of water into the soil zone, unsaturated zone and ultimately the saturated zone. This term is commonly combined with other terms to indicate some specific mode of recharge such as recharge well, recharge area, or artificial recharge.

Stressor ....Physical, chemical and biological factors that are either unnatural events or activities, or natural to the system but applied at an excessive or deficient level, which adversely affect the receiving ecosystem. Stressors cause significant changes in the ecological components, patterns and processes in natural systems.

Surficial sands ....Located in the interval of unconsolidated soil above the first bedrock formation.

Total Dissolved Solids ....Concentration of all substances dissolved in water (solids remaining after evaporation of a water sample).

Trend...The relationship between a series of data points (e.g., Mann Kendall test for trend).

Water-bearing ....Containing water within the spaces between sediment grains or established fractures.

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Please note that in May 2012, the Government of Alberta brought together the ministries of Environment and Water and Sustainable Resource Development to create one ministry called Alberta Environment and Sustainable Resource Development.

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