Summary of the Oil Sands Groundwater – Surface Water Interactions Workshop

Oil Sands Research and Information Network and Canadian Environmental Assessment Agency

June 2012

OSRIN
Oil Sands Research and Information Network

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OSRIN is a university-based, independent organization that compiles, interprets and analyses available information about returning landscapes and water impacted by oil sands mining to a natural state and provides knowledge to those who can use it to drive breakthrough improvements in reclamation regulations and practices. OSRIN is a project of the University of Alberta's School of Energy and the Environment (SEE). OSRIN was launched with a start-up grant of $4.5 million from Alberta Environment and a $250,000 grant from the Canada School of Energy and Environment Ltd.

OSRIN provides:

- **Governments** with the independent, objective, and credible information and analysis required to put appropriate regulatory and policy frameworks in place
- **Media, opinion leaders and the general public** with the facts about oil sands development, its environmental and social impacts, and landscape/water reclamation activities – so that public dialogue and policy is informed by solid evidence
- **Industry** with ready access to an integrated view of research that will help them make and execute reclamation plans – a view that crosses disciplines and organizational boundaries

OSRIN recognizes that much research has been done in these areas by a variety of players over 40 years of oil sands development. OSRIN synthesizes this collective knowledge and presents it in a form that allows others to use it to solve pressing problems. Where we identify knowledge gaps, we seek research partners to help fill them.

Citation

This report may be cited as:

Oil Sands Research and Information Network and Canadian Environmental Assessment Agency, 2012. *Summary of the Oil Sands Groundwater – Surface Water Interactions Workshop*. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta. OSRIN Report No. TR-22. 125 pp.

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REPORT SUMMARY

A number of factors led to the need for a workshop to discuss surface water – groundwater interactions in the oil sands. These included:

- Current government policies and the development of new policies and frameworks
- Continued uncertainty regarding the potential for interactions and the resulting impacts, particularly for fisheries habitat and resources
- Initiation of the Cumulative Environmental Management Association's Groundwater Working Group and their initial research results
- Work being undertaken by industry, particularly in the Southern Athabasca Oil Sands

The Workshop:

- Considered mineable and in-situ oil sands operations in general (i.e., did not focus on specific geographic regions, except when discussing specific examples)
- Focused mainly on groundwater (quality and quantity) – with discussion of surface water being limited to "groundwater – surface water interaction"
- Acknowledged, but did not address, that the different regulators have different responsibilities and authorities regarding groundwater, surface water and fisheries impacts related to interactions

The objectives of the Workshop were to:

- Develop a common understanding of the current knowledge regarding groundwater resources, groundwater-surface water interactions in the oil sands area, ongoing applied research, monitoring and potential impacts
- Develop recommendations regarding research, monitoring, modelling, etc. to address knowledge gaps and/or regulatory and environmental protection issues

The Workshop was structured with initial presentations by several speakers to set the context, and summarize current policy and recent research. The participants were then asked to respond to a series of general and topic-specific questions.

The report recommendations have not been directed to any specific individual or organization. Rather, the Steering Committee members will bring the recommendations back to their respective management teams for further consideration.

ACKNOWLEDGEMENTS

The Oil Sands Research and Information Network (OSRIN), School of Energy and the Environment (SEE), University of Alberta, the Canadian Environmental Assessment Agency and Natural Resources Canada provided funding for this project.

The Oil Sands Research and Information Network and the Canadian Environmental Assessment Agency are grateful for the work of the Workshop Steering Committee, the speakers and attendees for making the Workshop a success. Particular thanks to Michelle Camilleri and Solange LeBlanc, Canadian Environmental Assessment Agency for coordinating the work of the Workshop Steering Committee and the facilities, respectively.

DISCLAIMER

Workshop participants were encouraged to be open in the discussions to ensure the broadest range of views was captured. Their views were documented directly from the session worksheets with minimal editing.

The views expressed in this report do not necessarily reflect the views of OSRIN, any of the participating government agencies, academic organizations or companies.

1 INTRODUCTION

A number of factors led to the need for a workshop to discuss surface water – groundwater interactions in the oil sands. These included:

- Current government policies and the development of new policies and frameworks
- Continued uncertainty regarding the potential for interactions and the resulting impacts, particularly for fisheries habitat and resources
- Ongoing activities to develop systems to manage cumulative effects in the oil sands region
- Initiation of the Cumulative Environmental Management Association's Groundwater Working Group and their initial research results
- Modeling work being undertaken by industry, particularly in the Southern Athabasca Oil Sands

1.1 Focus and Objectives of the Workshop

The Workshop:

- Considered mineable and in-situ oil sands operations in general (i.e., did not focus on specific geographic regions, except when discussing specific examples)
- Focused mainly on groundwater (quality and quantity) – with discussion of surface water being limited to "groundwater – surface water interaction"
- Acknowledged that there has been considerable groundwater work undertaken in other jurisdictions which could help ensure the oil sands efforts are *best in class*
- Acknowledged, but did not address, that the different regulators have different responsibilities and authorities regarding groundwater, surface water and fisheries impacts related to interactions

The objectives of the Workshop were to:

- Develop a common understanding of the current knowledge regarding groundwater resources, groundwater-surface water interactions, ongoing applied research, monitoring and potential impacts
- Develop recommendations regarding research, monitoring, modelling, etc. to address knowledge gaps and/or regulatory and environmental protection issues

It was evident during the Workshop that there are a number of government, government/industry and government/industry/stakeholder organizations working on groundwater and surface water initiatives in the oil sands region. Workshop participants did indicate a need for a better understanding of roles and relationships between the organizations; such clarity would help direct the recommendations to the appropriate organization(s).

The Workshop participants viewed the exercise as an ideal opportunity to learn about the current state of knowledge and to develop working relationships with other experts. The general sense was that it was too early in the process to be able to state that particular technical points were *issues or concerns*, rather they are areas where more information is required.

The report recommendations have not been directed to any specific individual or organization. Rather, the Steering Committee members will bring the recommendations back to their respective management teams for further consideration.

1.2 Workshop Steering Committee

A Steering Committee composed of the following organizations developed the workshop structure and participant invitation list:

- Alberta Environment and Sustainable Resource Development (AESRD)
- Canadian Environmental Assessment Agency
- Cumulative Environmental Management Association (CEMA)
- Energy Resources Conservation Board
- Environment Canada
- Natural Resources Canada

1.3 Workshop Format

Technical experts from a variety of regulatory, research and academic organizations were invited to the workshop (see Appendix 1 for a list of the organizations that participated in the workshop).

The Workshop was structured with initial presentations by several speakers to set the context, and summarize current policy and recent research (The Workshop Agenda is provided in Appendix 2 and Presentation PowerPoints are provided in Appendix 3).

Participants were assigned to six tables allowing for a mix of organizations and expertise at each table. The participants were then asked to respond to a series of questions and given the following guidance to help focus the discussions.

When responding to the questions identified below participants were asked to consider, where appropriate:

1. Whether they are in agreement with the approach/task;
2. If the task or something very similar to it has already been completed;
3. Who should take the lead or support the implementation of the task;
4. What resources are required;
5. How the task can be best implemented;

6. The priority of the approach/task in relation to the other tasks identified; and
7. If the task is achievable within a one year timeframe.

All tables responded to a suite of general questions (section 4) and then pairs of tables were randomly assigned to specific focus-area questions (sections 5 to 7).

1.4 Structure of this Report

Section 2 provides the context for the discussions, and Appendix 3 provides copies of the presentations made at the start of the workshop. Section 3 provides the key observations and conclusions arising from the Workshop. Sections 4 to 7 provide the Steering Committee's summary of the discussions of the workshop participants. Appendix 4 provides the answers to the questions from the discussion tables.

The views presented in sections 3 to 7 and Appendix 4 in this report do not necessarily reflect the views of the various participating organizations.

2 CONTEXT FOR THE WORKSHOP DISCUSSIONS

A considerable amount of policy, monitoring and research work has been done to date and/or is being planned in the area of groundwater – surface water management. Presentations were provided outlining current state of knowledge (Appendix 3). The following provides a brief summary of the presentations and additional relevant information.

2.1 Groundwater Stressors

Both mining and in-situ oil sands developments result in impacts to groundwater resources. Potential impacts affecting groundwater levels (i.e., the water table in unconfined aquifers and potentiometric surfaces in confined aquifers) are related to dewatering in the mineable area, and withdrawals and injection in the in situ area. Once pumping ceases in these areas, the groundwater levels are predicted to re-establish themselves. In the minable area, groundwater levels may establish themselves at a new equilibrium dictated by the reclaimed landscape.

In addition to the groundwater level and flow impacts, there may be quality impacts arising from exposure to the industrial processes. In the minable area, potential groundwater quality impacts include seepage from large point sources at surface like tailings ponds, or tailings sediments placed for reclamation purposes. In the in situ area, potential impacts to groundwater quality primarily relate to thermal transport.

The mining footprint will increase but is bounded within the areas where the oil sands resource is shallow enough to economically warrant mining. The in situ footprint will expand over a larger area depending on the location of oil sands reservoirs.

2.2 Regulatory Interface

As noted in the presentations, there are a number of points in the project-development cycle where the regulators are involved in groundwater management decisions. Two key regulatory interaction points were noted as drivers for the Workshop and were raised by participants in the Workshop:

- At the environmental assessment stage, regulators must determine if there is sufficient information available such that they understand what the potential impacts to the groundwater, surface water and fisheries resources will be and how those impacts will be mitigated
- During the life of the project, the regulators must determine the level and type of monitoring to be done and how to address the monitoring results (adaptive management approach)

2.3 Alberta Environment and Sustainable Resource Development – Groundwater Regulation

A variety of tools and instruments are used to regulate groundwater in Alberta, including oil sands development areas.

The *Environmental Protection and Enhancement Act* (EPEA) specifies the requirements for the Environmental Assessment process. In certain cases, particularly for oil sands projects, this process is aligned with the Energy Resources Conservation Board's (ERCB) hearing process and/or the federal government's environmental assessment process.

EPEA also specifies requirements regarding Approvals issued to regulate various types of industrial, commercial and municipal activities, including specifying what activities and facilities require an Approval. Groundwater monitoring and management plans are usually required under Approvals issued to oil sands projects.

The *Water Act* specifies the requirements for the allocation and management of provincial water resources, primarily from a quantity perspective. Licenses are Approvals are issued under the *Water Act* for diversions or disturbances of water bodies, including groundwater, often with monitoring and other conditions to ensure water resources are protected.

2.4 Alberta Environment and Sustainable Resource Development – Groundwater Management Frameworks in the Lower Athabasca Region

More recently regional planning initiatives under the *Alberta Land Stewardship Act* (ALSA) are being used to manage cumulative effects in six major regions covering the province. The Lower Athabasca Regional Plan (LARP) uses Groundwater Managements Frameworks to manage groundwater in oil sands development areas.

The goal of the Groundwater Management Frameworks (GWMF) is to provide a system to manage groundwater resources (quantity and quality) in a sustainable manner and to protect from contamination or over use. The goal is also to develop a consistent approach that manages cumulative effects of non-saline groundwater across the LARP region.

Each management framework:

- Assesses the current state of groundwater resources within the study area

- Defines / refines the baseline and range of natural variability
- Provides a means to detect and assess changes to groundwater resources from future development or natural events.

The frameworks include three key components:

- **Establishment** of scientifically-based target and threshold values based on current level of knowledge and data for identified effects indicators.
- **Monitoring** to assess the condition of groundwater quality and quantity within key aquifers.
- **Management** actions will be responsive to the evaluation process and will be tailored to specified targets and thresholds to ensure sustainability of regional groundwater resources.

The established regional groundwater monitoring networks will ensure timely detection of changes to key effects indicators that warrants response, investigation and possible mitigation. Data collected will be evaluated and communicated on a regular basis. Implementation of the GWMFs will consist of the development of Groundwater Management Plans by EPEA approval holders. Development of a comprehensive Regional Groundwater Monitoring Networks across the region is one of the commitments of the framework. The Regional Groundwater Monitoring Evaluation and Reporting (RGMER) Group has been established to develop regional groundwater monitoring networks and to implement regional groundwater monitoring programs in each of the three management areas.

To ensure groundwater resources in the Lower Athabasca Region are managed sustainably, the Alberta Environment and Sustainable Resource Development has developed a Draft Groundwater Management Framework. The Framework subdivides the Lower Athabasca Region into 3 distinct groundwater management areas:

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

2.5 Energy Resources Conservation Board (ERCB)

The ERCB is one of the regulatory agencies responsible for the upstream oil and gas industry, and its mission is to ensure development is safe, fair, responsible and in the public interest.

The location and a brief summary of the geology of the Athabasca and Cold Lake Oil Sands areas, plus an overview of mining and in situ extraction methods and the water needs for both is provided in the presentation in Appendix 3.

The ERCB application review process was described, noting that the social, environmental and economic aspects of a proposed project are components of the assessment process. Larger projects may require an Environmental Impact Assessment (EIA) and the review process would include other reviewing agencies.

It was stressed that an understanding the geology and hydrogeology is key to an assessment of a proposed project. This is essential to understanding the potential for groundwater – surface water interactions, the water source options, and reservoir and disposal zone containment. The groundwater specific component of the review considers the proposed projects potential to impact groundwater, the appropriateness of proposed mitigations and if project revisions are necessary to ensure groundwater is protected. Data from geophysical well logs, core, monitoring wells, and seismic programs are the primary data sets used in these assessments.

ERCB assigns monitoring and reporting requirements to its approvals and conducts surveillance throughout the life of a project.

2.6 Alberta Geological Survey

The Alberta Geological Survey (AGS) is responsible for improving and updating knowledge of the provincial geological framework and disseminating this information.

On a provincial scale, the AGS is focused on developing an inventory of non-saline groundwater (less than 4,000 milligrams per litre total dissolved solids) as part of its Provincial Groundwater Inventory Program in partnership with Alberta Environment and Sustainable Resources Development (AESRD). The purpose of this program is to evaluate the quantity, quality and thresholds between sustainable and unsustainable groundwater uses. The program's findings in the Edmonton – Calgary Corridor have recently been published in a Groundwater Atlas. The AGS is now continuing this inventory work in other parts of the province.

AGS is also characterizing saline aquifers on a provincial scale as part of the Saline Aquifer Mapping Project that is focusing on evaluating aquifers for groundwater production, storage and retrieval, geothermal and CO_2 sequestration.

Previous AGS work on Quaternary channels in northeastern Alberta is widely used by industry and regulators. Currently, AGS projects in the oil sands areas involve better defining the carbonate succession through high-resolution mapping of structure and karst features. In addition, a project undertaking a geological and geomechanical characterization of the units within and above the bitumen resource is evaluating potential caprock integrity issues. All these projects provide valuable information used in the development of Alberta's oil sand resources.

2.7 Environment Canada

2.7.1 *Purpose and Genesis of Integrated Monitoring Plan*

In February 2012, the governments of Canada and Alberta announced the phased implementation of the oil sands monitoring plan. The integrated monitoring plan was developed to provide an improved understanding of the state of the environment and how cumulative effects from multiple stressors alters physical, chemical and biological processes and local and regional water quality/quantity, air quality and aquatic and terrestrial biodiversity.

Phase 1 deals with physical and chemical aspects of the Athabasca River mainstem and its major tributaries, between Fort McMurray to Wood Buffalo National Park Boundary. Monitoring components include surface and groundwater, hydrology, sediments, climate and air deposition (Environment Canada 2011a). Phase 2 expands the geographic scope to include the Peace Athabasca Delta, Lake Athabasca, the Slave River systems, and upland acid sensitive lakes in the region that could be affected by aerial deposition, including northern Saskatchewan (Environment Canada 2011b).

A mass balance approach has been used in designing the monitoring network assessing the quantity, movement and cycling of materials in the watershed. The major contaminant input sources that must be considered are:

- direct surface water point sources (i.e., industrial/municipal end of pipe inputs)
- diffuse non-point sources from the landscape (i.e., indirect aerial deposition, overland flow, site drainage, erosion)
- groundwater inputs (including seepage/leakage from tailings ponds and groundwater – surface water interactions)
- direct aerial deposition

Within this broader focus, four elements of the groundwater studies include:

- Ecological focus on groundwater – surface interactions
- Relative importance and contribution of groundwater quality and quantity to surface waters
- Assessment of nature and extent of seepage from tailings facilities to surface water
- Characterization of ambient groundwater conditions and natural variability

2.7.2 *Methods*

Estimation of groundwater seepage and possible surface water interactions requires a broader synoptic approach to spatial sample placement and related temporal frequency. A series of distinct geographic (mainstem and tributary) sampling regimes will be used to characterize the groundwater quality (and its variability) discharging to the reach under examination (with an appropriate number of replicates taken for QA/QCs purposes). For example, in areas more distant from oil sands operations and tailings ponds, spatial sampling will be less dense. Sample densities proximate to tailings ponds (e.g., Suncor Pond 1) will be approximately 50 to 150 m apart (i.e., based on preliminary Environment Canada studies in the vicinity of Suncor's Pond 1; about 70 samples along the 4 km shoreline). Adjustments to site spacing will be conducted if deemed necessary after preliminary analyses.

Within the Athabasca mainstem, riverine groundwater sampling will build on existing tailings pond studies and sites currently being used by Environment Canada and Alberta Environment and Sustainable Resource Development. Riverine groundwater samples will be collected during four time intervals (summer, spring, autumn, winter), with the initial proposed levels of site replication focused on operations closest to surface water and new areas scheduled for development.

Groundwater chemical analytes to be measured will be the same as described for the surface water stations.

Proposed next steps of the Joint Monitoring Plan with respect to groundwater include:

- Screen tributaries for groundwater discharge using isotopic and geochemical indicators
- Map groundwater discharge and quantify groundwater fluxes in locations identified in screening
- Monitoring groundwater quality from areas identified in discharge mapping

2.8 Department of Fisheries and Oceans (DFO)

DFO reviews project proposals for potential impacts to fish habitat resulting from, for example, placement and construction of surface infrastructure, groundwater withdrawals resulting in reduction in surface flows during low flow periods, as well as the potential for surface heave to alter watercourse morphology. Through the in-depth groundwater – surface water interaction review process, it has become apparent that uncertainty exists with respect to the potential for these interactions (i.e., reduction in surface low flow and the resulting impacts to fish habitat).

Generally, the groundwater models utilized in the environmental assessment analysis provide relatively accurate assessments for regional groundwater flow, although the capability of the models to detect and interpret potentially subtle interfaces (e.g., location, magnitude, seasonality, etc.) of groundwater – surface water interactions affecting surface flows and fish habitat may be limited.

Factors complicating the assessment include the collection of baseline data, where in some cases the proposed project is in a relatively undisturbed landscape and access to the site for the collection of field data can be onerous if not impossible during some seasons. With limited baseline data, it is difficult to assess the accuracy of predictions of environmental effects made in the environmental assessment.

Several challenges exist with the determination and interpretation of data, including:

- Challenges of establishing sub-surface baseline conditions include: number of sampling events typically required for statistical significance; narrow window of time between gaining access, baseline monitoring, project application and monitoring during disturbance; seasonal variation in flow rates depending on the aquifer; local anomalies depending on the hydrogeology (integrity and heterogeneity of overlying confining beds will determine degree of hydraulic connection between aquifers and the quantity of leakage).

- There are additional challenges found in identifying the sub-surface hydraulic connections of groundwater to surface water including sufficient data available to address spatial and temporal variation in sub-surface conditions, and sensitivity of surface water features present. As well, the location of buried channels and their possible interaction with incised surface water receptors also influence possible groundwater – surface water interactions. There are uncertainties associated with the models and measurement of low flows (measurement errors inherent in measuring flows under ice; the relative contribution of groundwater discharge to low surface flow as it may also be derived from other sources such as lake discharge).
- There is also the challenge of getting a monitoring network in place and the data collected prior to groundwater impacts having occurred.

Generally there is a broad regional understanding of groundwater systems, however there are local and site specific hydrogeologic anomalies that must be understood to better assess potential impacts to fish habitat resulting from development. One example of environmental assessment information that captures this uncertainty with respect to groundwater – surface water interactions states:

> *The groundwater model is a numerical representation of a dynamic, multi-layered local-to-regional groundwater system. The level of uncertainty in such a relatively complicated hydrogeologic system is high ... Collection of spatio-temporal data under a groundwater monitoring plan will enable periodic reassessment of the model's representativeness … Until then, the model is a useful but rather broad guide to potentially subtle interfaces, such as zones of groundwater/ surface water interchange* (Dover OPCO Vol. 4, Sec. 2, pp. 2-17).

3 GENERAL OBSERVATIONS AND CONCLUSIONS

The Workshop provided a much needed opportunity for provincial and federal regulators to discuss current state of knowledge on regional groundwater issues and regulatory processes. It is recommended that a workshop such as this be held every year (with broader participation from industry and consultants) to allow for a more comprehensive understanding of issues and activity. Such a workshop could then be followed up by a meeting of the regulators to discuss next steps.

While the participants developed a better understanding of the existing state of knowledge, there were specific areas where more detailed information was desired. This knowledge could be shared through additional workshop sessions. Examples include:

- Describe the status of the Southern Athabasca Oil Sands modeling work done to date and potential to expand/extrapolate to the larger region.
- Describe the existing sites and the current priorities of the Northern Athabasca Oil Sands, Southern Athabasca Oil Sands and Cold Lake Beaver River groundwater monitoring network.

- Describe existing data, models, monitoring and the relationships between these.

The following concepts arose several times during the workshop and require further work:

- Development of a common database to allow for better data integration, sharing, transfer and overall management.
- Need for additional information regarding:
    - Devonian formations;
    - Recharge rates; and
    - Intersection between knowledge and data for geology, hydrogeology, groundwater and surface water to properly understand interactions.
- Model development, validation and outputs.

The Steering Committee will poll participants to determine any other information needs so that relevant sessions could be organized over the next year.

4 RESPONSES TO GENERAL QUESTIONS

4.1 Likelihood of Interactions and Their Impact

Question: Do you feel there are or will likely be groundwater surface water interactions as a result of mineable and in-situ oil sands operations? If so, do you expect them to be positive, negative or neutral?

In general, the participants agreed there were likely to be interactions and that they would be more pronounced in the mineable oil sands area due to the need to dewater prior to and during mining than in the in-situ area. The participants indicated that the expected magnitude of the impacts is uncertain and may depend on the timeframe under consideration – short term impacts may be greater than long term ones.

Mining operations are likely to have a wider impact (areal extent) than in situ operations.

4.2 Appropriateness of Indicators

Question: Are the proposed indicators appropriate/adequate for the purposes of assessing the condition of regional groundwater quantity and quality? If not, what should be changed (i.e., added/removed)?

A number of participants felt the indicators proposed under the Lower Athabasca Regional Plan are appropriate but there were also a number of additional specific technical indicators mentioned for both quality and quantity measures.

4.3 Triggers and Limits Approach

Question: Is the use of triggers and limits to generate effective management actions a realistic approach?

In general, the use of a triggers and limits approach was felt to be appropriate but the participants provided a number of caveats which suggests further work is required to establish an appropriate system for surface – groundwater interactions. Issues such as timeframe, scale (local vs. regional and well vs. local vs. regional) and ability to identify a responsible party if a problem arises were raised.

The participants identified the need to quickly develop a baseline condition and then track trends over time. Participants also indicated that the system should be subject to refinement as knowledge is generated (i.e., an adaptive management approach).

4.4 Regional Groundwater Monitoring Evaluation and Reporting Group

Question: Is there anything that should be added or changed with respect to the newly formed Regional Groundwater Monitoring, Evaluation and Reporting Group?

There was a range of understanding about the role, makeup and accountability of the Regional Groundwater Monitoring, Evaluation and Reporting Group. Participants provided some suggestions on administrative and technical matters the Group should consider.

5 RESPONSES TO CHEMISTRY AND WATER QUALITY QUESTIONS

5.1 Arsenic

Question: Arsenic issues have been identified in the in-situ area. Are there any potential arsenic issues, natural and/or anthropogenic, that should be considered in mineable areas?

Given experience in the Cold Lake area it was felt that arsenic should be considered an issue for in situ operations until proven otherwise. Arsenic in the mineable oil sands region should be investigated and taken off the table if it is shown not to be an issue. Access to existing data sources was seen as important.

5.2 Assemble Existing Data

Question: Should we assemble existing data from AESRD, ABMI, RAMP, LTRN etc. to generate regional maps of geochemical indicators of increased surface water – groundwater connectivity?

Participants agreed that existing data should be assembled into a regional database. Such a database should be a collaborative effort of industry and government. It should be cost-shared and perhaps maintained by a third-party.

5.3 Use Existing Baseline Hydrology Water Quality and Water Balance Data

Question: Should we use existing baseline hydrology, water quality and water balance data (as available) collected by Southern Athabasca Oil Sands (SAOS) operators and compare to annual assessments of site-specific hydrology (using isotope mass balance models) and distributions of runoff parameters to identify types of surface water settings that may be vulnerable to changes in groundwater contributions.

Participants were split on using the existing data, with particular uncertainty around the scope of the data. This suggests a need for a future workshop session so that the Southern Athabasca Oil Sands operators could explain the work done to date and potential to expand/extrapolate to the larger region.

5.4 Develop List of Regional and Local Scale Issues

Question: In the context of developing a model strategy, should we develop a list of regional and local scale issues that will need to be addressed by numerical modelling, rank in terms of priority. Identify major flow and solute transport processes that need to be included to address these issues.

Developing a list of issues will help to develop a useful model.

5.5 Other Priority Work

A number of issues were identified for additional work. The need for a detailed groundwater inventory came up more than once, as did the need for a hydrogeological model. The two core items would allow for better sustainable planning of groundwater use.

6 RESPONSES TO MODELING QUESTIONS

Although the Workshop participants were given very specific questions the participants focused on the general issue related to modeling and data collection. There were differing views on which was more important – development of a model or collection of more data.

There was general recognition that models are just one of many tools to assist companies and regulators in making project decisions. However it was also noted that models and their predictions are used extensively in Environmental Impact Assessment work supporting the public interest decision and therefore more confidence in their underlying assumptions, data and results is needed. One way to improve confidence is to continue to refine the models based on new information and monitoring results.

6.1 Other Models

Question: Are there models other than FEFLOW that would be more appropriate? What model scenarios would you suggest be considered for Phase 2 of the presently developed model? How do we apply the most effectively developed model to achieve our objectives?

The participants identified pros and cons for FEFLOW[1]. Other models, including MIKE 11[2], MIKESHE[3] and MODFLOW[4], were mentioned. Participants also noted some characteristics of a "good" model.

6.2 Moving from Regional Scale to Project Scale

Question: How can the regional scale monitoring network/modelling be applied at the project scale?

Regional modeling can help identify potential local issues that require analysis. Data collection at the local-scale can be used to improve regional models (a virtuous cycle). Both regional and local models can be used to provide regulatory consistency across projects in close proximity.

6.3 Information Required to Improve and Constrain Models

Question: Should we consult with modellers to identify which information should be collected to improve and constrain the predictive work around active surface water – groundwater interactive regions. In the group discussion consider what information you would like to see collected during this task.

There was a sense that more effort should be placed on data collection rather than refining models at this time. More data will allow for a better understanding of the geology and hydrogeology, water chemistry, and changes in surface water bodies (notably wetlands). However, it was noted that models do help focus monitoring work by noting where data gaps exist.

6.4 Desktop Survey of Models

Question: Should we perform desktop survey of available surface water – groundwater interaction models currently available, including those already in use in the Lower Athabasca Region?

It was noted that this may already have been done, and in any case is a low priority.

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[1] See http://www.feflow.info/

[2] See http://www.dhigroup.com/upload/publications/brochures/MIKE_11.pdf

[3] See http://www.crwr.utexas.edu/gis/gishyd98/dhi/mikeshe/Mshemain.htm

[4] See http://www.modflow.com/modflow/modflow.html

6.5 Identify Advantages and Drawbacks of Models

Question: Should we identify advantages and drawbacks of each model identified in task 4 and assess ability to successfully address priority issues of concern in the Lower Athabasca Region? In the group discussion consider what else we could do, other that identify the disadvantages and drawbacks of each models.

It was noted that this may already have been done in 2007, and is therefore a low priority.

6.6 Inventory and Evaluate Models

Question: In the context of developing a modeling strategy should we take stock of models and techniques currently being used in context of surface water - groundwater interaction; perform independent evaluation of current models to assess their relative quality and prediction veracity.

Data gaps on regional scale create significant challenges in being able to achieve this. Therefore, data collection is key/top priority right now.

6.7 Other Priority Work

Common themes identified include: mapping of surficial geology and shallow aquifers; expanding the monitoring network, accessing Traditional Ecological Knowledge regarding the locations of important springs, developing a modeling strategy and developing a common database.

7 RESPONSES TO HYDROGEOLOGY AND HYDROLOGY QUESTIONS

7.1 Additional Groundwater Monitoring Sites

Question: Are there additional sites within the proposed (Southern Athabasca Oil Sands) and existing (Northern Athabasca Oil Sands, Southern Athabasca Oil Sands and Cold Lake Beaver River) groundwater monitoring network that should be added? Are there any key areas that should be addressed as priority areas?

More information is required on the existing sites and the current priorities (however a greater understanding of the vulnerability mapping is needed).

7.2 Influence of Devonian Formation

Question: How can we better understand the influence of Devonian formation waters on groundwater and the Athabasca River?

Participants identified the need to understand how to merge existing geology and hydrogeology data (with an emphasis on geochemistry, especially salts and metals) so that interpretations of potential impact can be made. A number of suggestions for further technical work were made.

7.3 Assessment and Determination of Recharge Rates

Question: Should a thorough assessment and determination of recharge rates in the oil sands area be considered a priority?

Yes, although discharge measurements are equally important and may help bring certainty to recharge.

7.4 Additional Monitoring Efforts

Question: Should we identify what additional monitoring efforts could be undertaken to provide more info on surface water – groundwater interaction? Surface Water – Groundwater monitoring programs can address priority issues like: Understanding/quantifying impacts on surface waters in the vicinity of surface mining activities; Understanding/quantifying impacts (if any) on surface water bodies; Understanding potential impacts, and mechanisms for impact, of in-situ development on groundwater.

The CEMA-AITF reports (WorleyParsons 2010a,b) were considered to be good reference documents. Water quantity needs (data and models) were mentioned more frequently than quality.

7.5 Use Predicted Shallow Aquifer Drawdowns

Question: In the context of developing a better understanding of in-situ development impacts should we use predicted shallow aquifer drawdowns (numerical models) to determine if areas with predicted changes in groundwater levels coincide with surface water features identified to strongly rely on groundwater inflows. Identify inputs/impacts of heave and source water withdrawal on interaction.

There was a view that this would help as long as validated against monitoring data, and is a logical progression from simple maps. There was also uncertainty around input data and modeling results in general suggesting a need for a future workshop on existing data, models, monitoring and the relationships between these.

7.6 Other Priority Work

There were a number of observations around the need for more transparency/access to data.

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9 ACRONYMS

ABMI	Alberta Biodiversity Monitoring Institute
AESRD	Alberta Environment and Sustainable Resource Development
AGS	Alberta Geological Survey
AITF	Alberta Innovates – Technology Futures
ALSA	*Alberta land Stewardship Act*
CEMA	Cumulative Environmental Management Association
CLBR	Cold Lake Beaver River
CONRAD	Canadian Oil Sands Network for Research and Development
EIA	Environmental Impact Assessment
EPEA	*Environmental Protection and Enhancement Act*
ERCB	Energy Resources Conservation Board
DFO	Department of Fisheries and Oceans
GWMF	Groundwater Management Frameworks
LARP	Lower Athabasca Regional Plan
LTRN	Long Term River Network
NAOS	Northern Athabasca Oil Sands
OSRIN	Oil Sands Research and Information Network
QA/QC	Quality Assurance / Quality Control
RAMP	Regional Aquatics Monitoring Program
RGMER	Regional Groundwater Monitoring, Evaluation and Reporting
SAOS	Southern Athabasca Oil Sands
SEE	School of Energy and the Environment
TEK	Traditional Ecological Knowledge

10 LIST OF OSRIN REPORTS

OSRIN reports are available on the University of Alberta's Education & Research Archive at https://era.library.ualberta.ca/public/view/community/uuid:81b7dcc7-78f7-4adf-a703-6688b82090f5. The Technical Report (TR) series documents results of OSRIN funded projects. The Staff Reports series represent work done by OSRIN staff.

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APPENDIX 1: Organizations Represented at the Workshop

The following organizations were represented at the Workshop:

Provincial Government

Alberta Environment and Water (now Alberta Environment and Sustainable Resource Development)

Alberta Geological Survey

Alberta Sustainable Resource Development (now Alberta Environment and Sustainable Resource Development)

Energy Resources Conservation Board

Federal Government

Canadian Environmental Assessment Agency

Department of Fisheries and Oceans

Environment Canada

Natural Resources Canada

Parks Canada

Transport Canada

Industry

Cenovus Energy

Devon Canada

MEG Energy

StatOil

Consultants and Researchers

Cumulative Environmental Management Association

University of Alberta

WaterSMART

Western Water Associates Ltd.

Worley Parsons

APPENDIX 2: Workshop Agenda

Time	Topic	Lead
0830 - 0845	**Welcome, Introductions**	**Shauna Sigurdson**
0845 - 0900	**Establishing the Context** • review objectives for the workshop including a brief introduction to the issues	**Shauna Sigurdson/Chris Powter**
0900 - 1000	**Regulatory/Emerging Issues** • Regulatory agencies will review current regulatory approaches to address potential groundwater impacts from oilsands developments • Identification of emerging issues from a regulatory perspective	**AEW, ERCB, AGS, DFO**
1000 - 1015	**Break**	
1015 - 1105	**Groundwater/Surface Water Monitoring and Modeling** • Overview of groundwater/surface water monitoring programs with an emphasis on their application to the environmental assessment and/or regulatory process	**EC and AEW**
1105 - 1205	**Results of Recent Literature Reviews** Overview of groundwater "initiatives" (this will include current research and mapping efforts) • Recommendations on how to implement panel recommendations and the LARP groundwater management framework • Scoping document on "surface-groundwater" interactions	**CEMA/Researchers**
1205 - 1245	**Lunch**	

Time	**Topic**	**Lead**
1245 - 1445	**Focused Group Discussions** • Discussion of (1) AEW groundwater framework and (2) the short term objectives relating to groundwater monitoring and modeling (based on CEMA presentation: Project Summary: surface water - groundwater interaction in the Lower Athabasca Region (LAR))	**All**
1445-1500	**Break**	
1500 - 1600	**Reporting and Discussion** • Groups will report out in plenary with an opportunity for questions	**Chris Powter**
1600 - 1630	**Wrap - up**	**Chris Powter**

APPENDIX 3: Workshop Presentations

The following presentations were made at the start of the Workshop to help set context and summarize policy development and recent research work.

Provincial

An approach to managing cumulative effects to groundwater resources in the Alberta Oil Sands – Margaret Klebek, Alberta Environment and Sustainable Resource Development

Alberta's Current Regulatory Framework and New Directions – Pat Marriott, Alberta Environment and Sustainable Resource Development

Oil Sands Developments and Groundwater – Brenda A. Austin, Energy Resources Conservation Board

Groundwater Initiatives at the Alberta Geological Survey – Dan Palombi, Alberta Geological Survey

Federal

Groundwater Monitoring in the Lower Athabasca: Overview of Activities & Groundwater Strategy for the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring – Greg Bickerton, Environment Canada

DFO and Groundwater – Surface Water Interactions – Court Berryman, Department of Fisheries and Oceans

Cumulative Environmental Management Association

Groundwater Monitoring in the LAR: Panel Conclusions and What's Next – Kim Sturgess, WaterSMART

Project Summary: SW-GW Interaction in the Lower Athabasca Region (L.A.R.) – Jon Paul Jones, Jean Birks and John Gibson, Alberta Innovates – Technology Futures

Groundwater Initiatives – Jon Fennel, WorleyParsons

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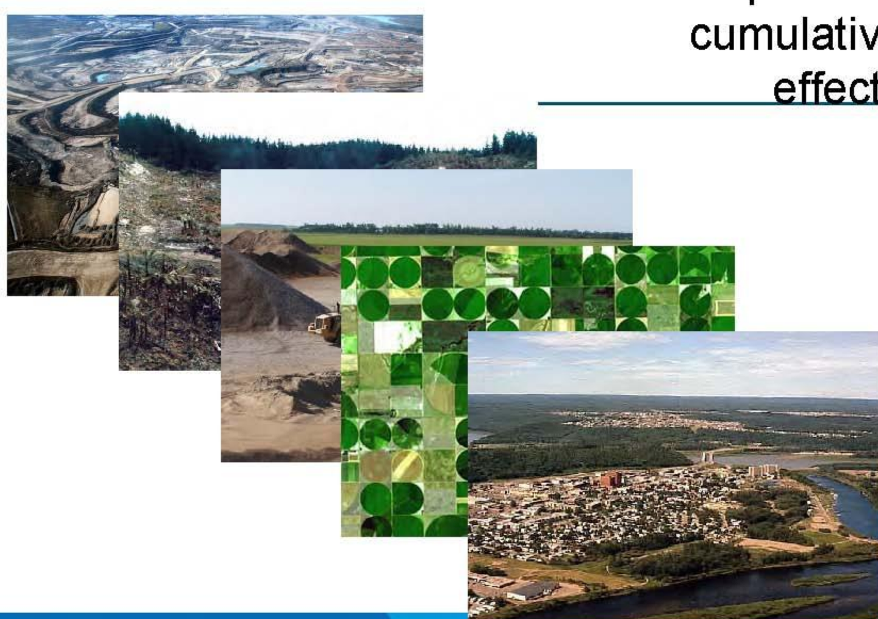
An approach to managing cumulative effects to groundwater resources in the Alberta Oil Sands

Margaret Klebek

Government of Alberta

Aspects of cumulative effects



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Issue

- Potential effects to groundwater quality and quantity from current and future oil sands projects& understanding of natural setting

Solution

- Development of a management framework (GWF) to guide stewardship of groundwater in the mineable and insitu development regions

Goal

- To managed cumulative effects using a science based approach, and to manage groundwater resources in a sustainable manner

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Challenges	Mineable oil sands In situ oil sands •Drawdown effects from dewatering for safe mine development. •Potential seepage from established waste management facilities and related mine structures. •Effects from disposal of mine depressurization water and process waste water by subsurface injection. •Physical and chemical effects from localized heating of subsurface by normal operation of thermally-enhanced oil recovery wells. •Pressure effects and constituent migration from waste injection activities. •Operational upsets (spills, leaks, casing failures, and releases of chemicals and hydrocarbons at processing facilities an related well infrastructure).
Related Inputs	• Salts, organics including naphthenic acids (NAs), metals, trace elements, phenols, low molecular weight (LMW) hydrocarbons and soluble PAHs. • Soluble salts and organics (including NAs), metals and trace elements; phenols and LMW hydrocarbons (including soluble PAHs)

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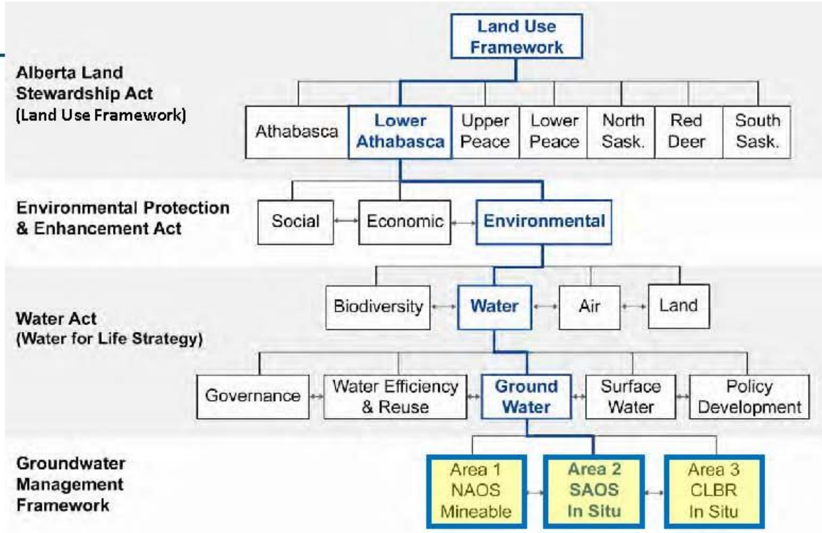
Management frameworks



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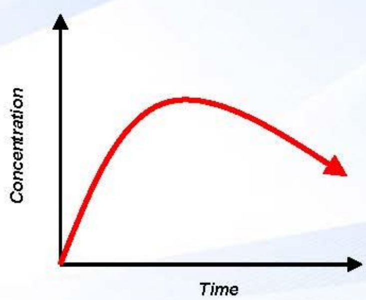
Guiding principles

- Cumulative effects management (& verification of EIA results)
- Pollution prevention / avoidance
- Reversal of adverse trends



Main components of draft GMF:

ESTABLISHMENT of scientifically-based trigger and limits values for identified effects indicators

MONITORING to assess the condition of groundwater quality and quantity within key aquifers

MANAGEMENT actions tailored to specified triggers and limits to ensure sustainability of regional groundwater resources

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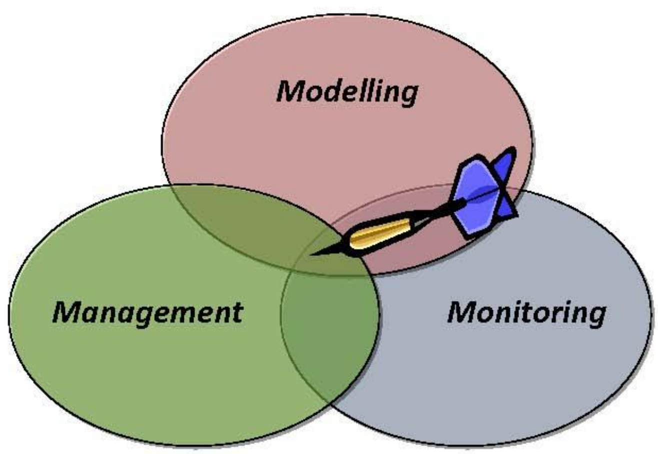
Integration of decision support tools



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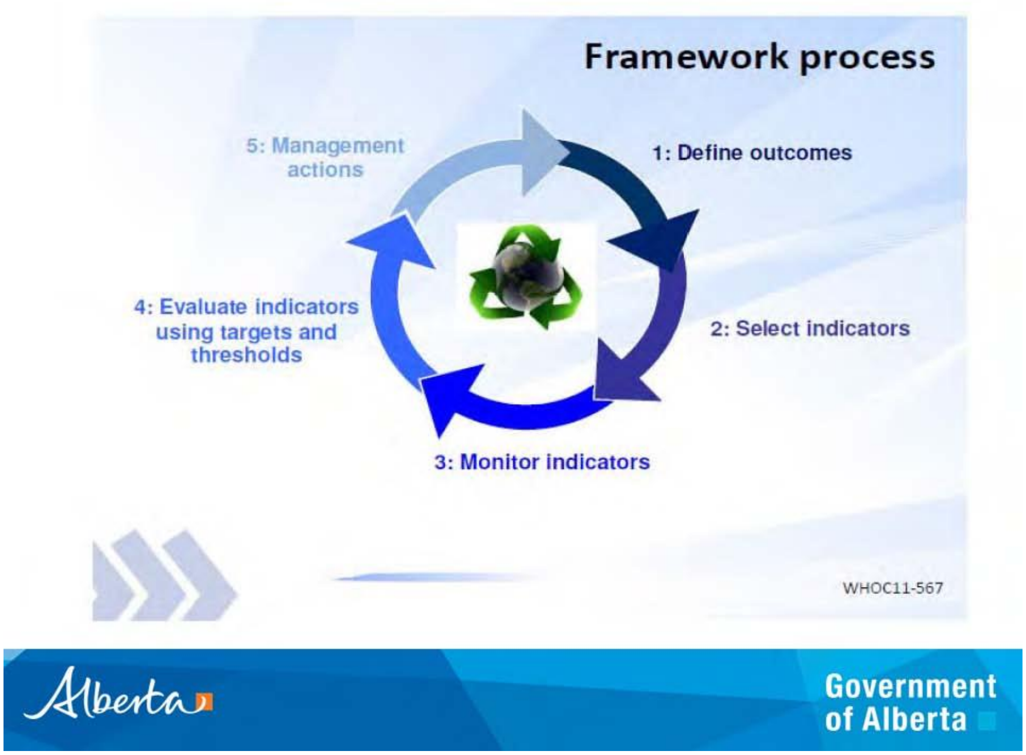
Framework process
1: Define outcomes
2: Select indicators
3: Monitor indicators
4: Evaluate indicators using targets and thresholds
5: Management actions
WHOC11-567
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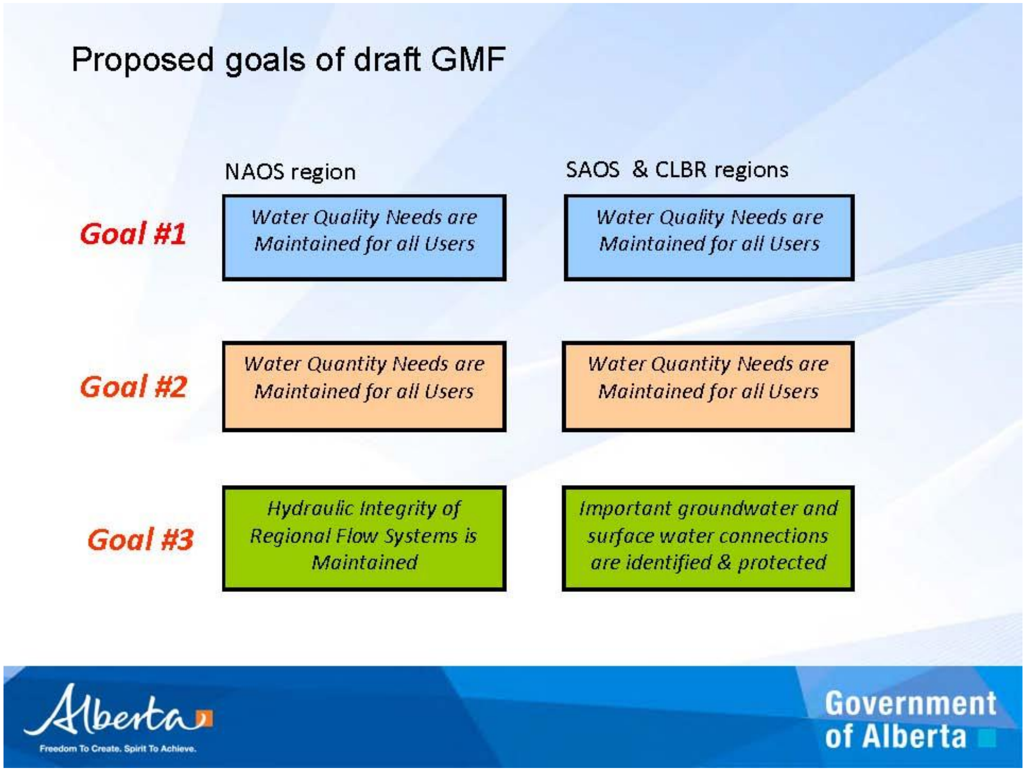
Proposed goals of draft GMF
NAOS region
SAOS & CLBR regions
Goal #1
Water Quality Needs are Maintained for all Users
Water Quality Needs are Maintained for all Users
Goal #2
Water Quantity Needs are Maintained for all Users
Water Quantity Needs are Maintained for all Users
Goal #3
Hydraulic Integrity of Regional Flow Systems is Maintained
Important groundwater and surface water connections are identified & protected
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Freedom To Create. Spirit To Achieve.
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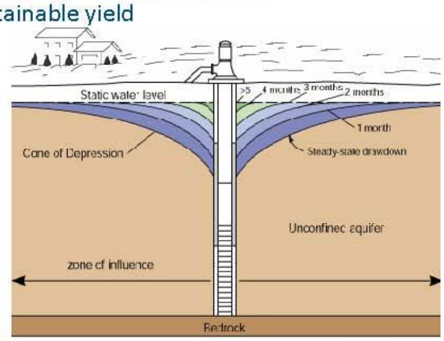
Proposed indicators

Quality

Sodium, Potassium, Chloride
Silicon, Strontium, Arsenic Barium,
Nitrate, Ammonia, Phenols, PHC F1,
selected isotopes

Quantity

Temporal water levels
Available head in key aquifers
Sustainable yield



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Proposed triggers and limits

Groundwater Quality	
Trigger	Upper Control Limit (statistically-derived)
Limit	Risk-based approach
Groundwater Quantity	
Trigger	Lower Control Limit (statistically-derived)
Limit	Risk-based approach

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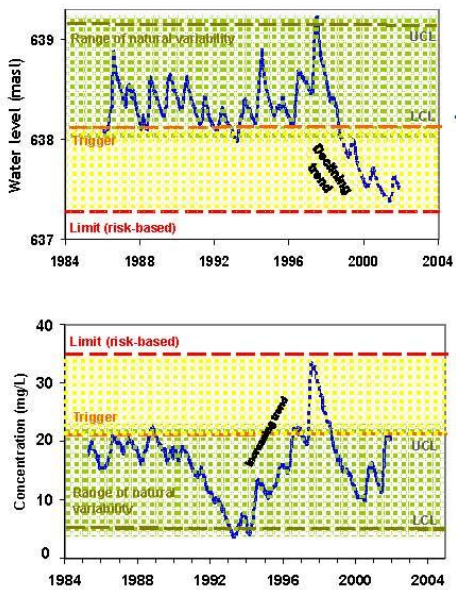

Proposed data analysis

- Statistical control charting and trend analysis to be utilized for selected indicator parameters
- Follow-up investigation process if trend identified or trigger exceeded

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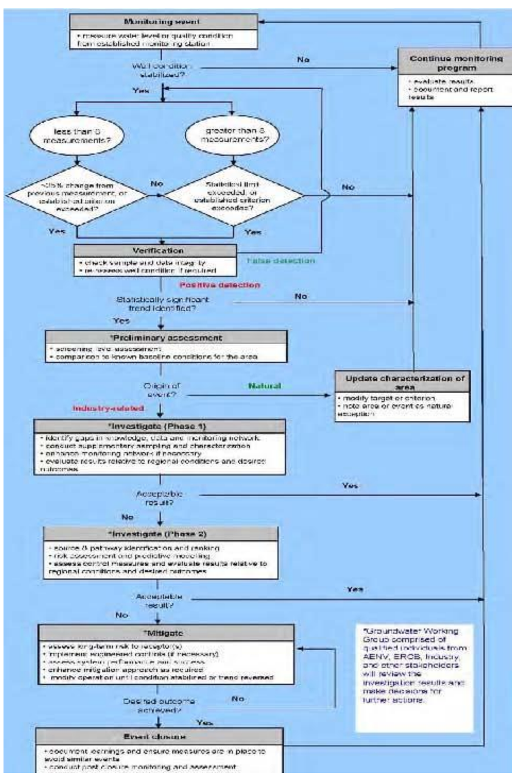

Proposed investigation & management process

- Exceedance of a trigger level will provoke an investigation into the source and cause
- Follow-up investigation will help facilitate understanding of the event or need for corrective action.

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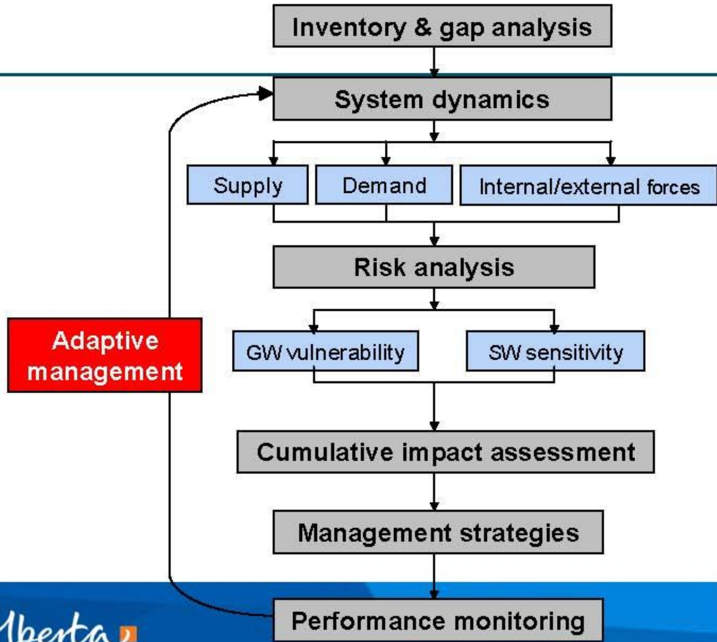
The Management Process



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An approach to managing cumulative effects to groundwater resources in the Alberta Oil Sands

- The Framework subdivides the Lower Athabasca Region into three distinct groundwater management areas:

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

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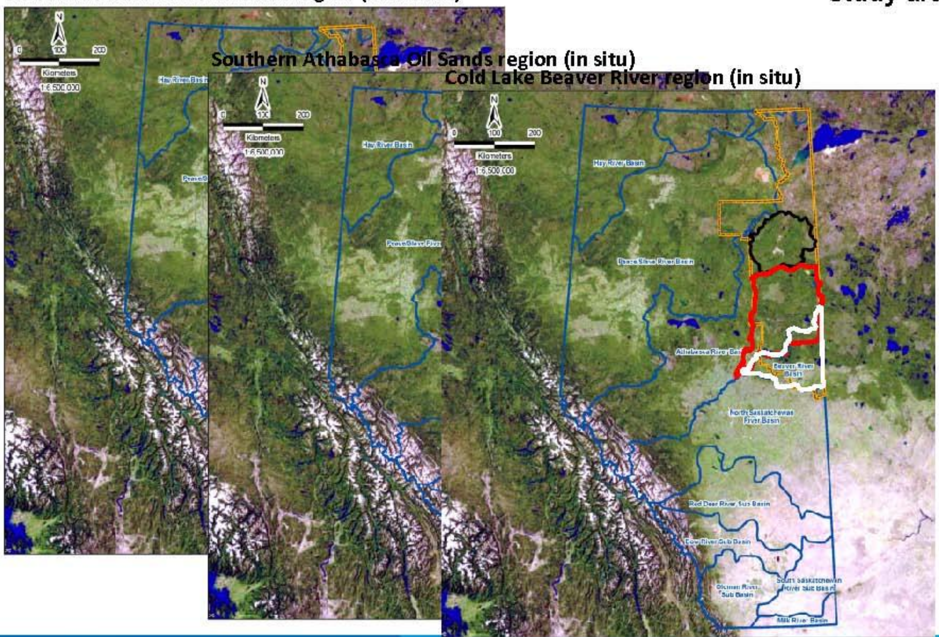
Study areas



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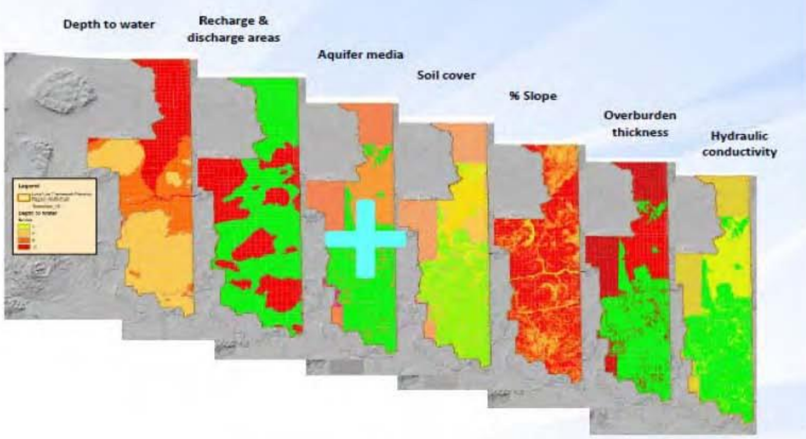
Intrinsic Vulnerability



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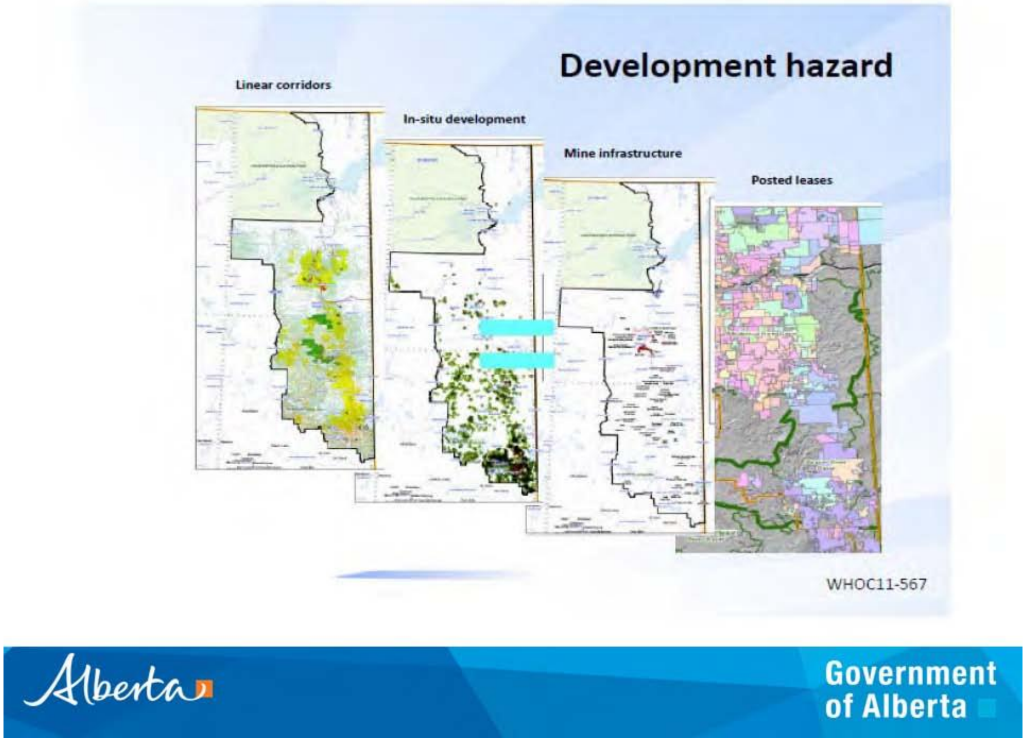
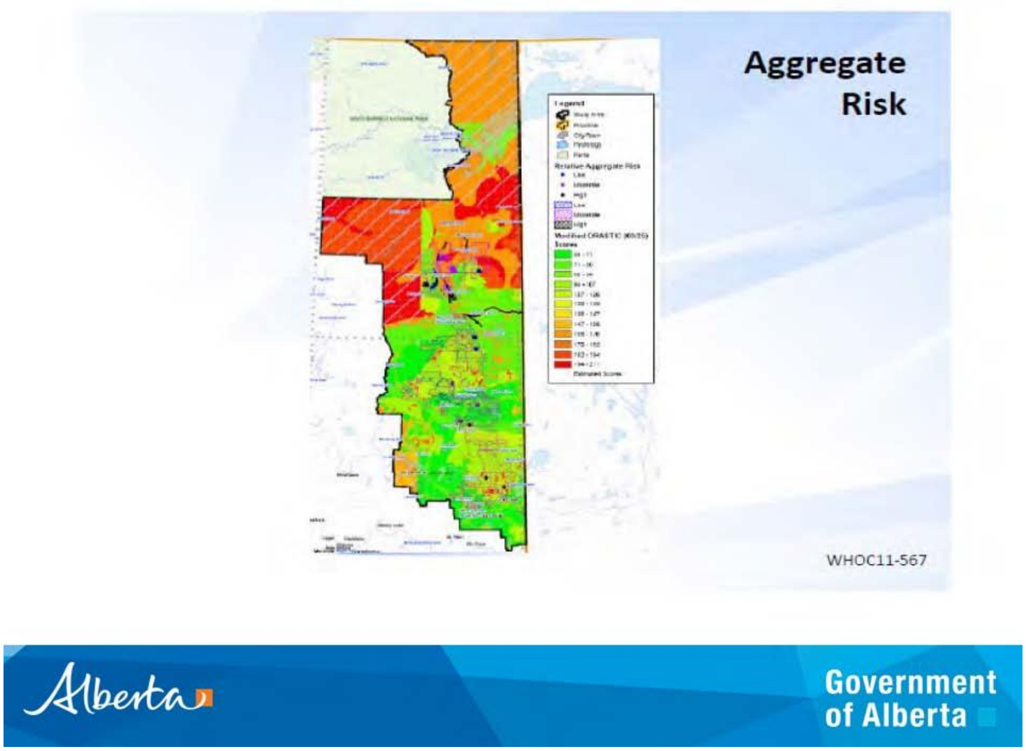

Development hazard
Linear corridors
In-situ development
Mine infrastructure
Posted leases
WHOC11-567
Alberta
Government of Alberta


Aggregate Risk
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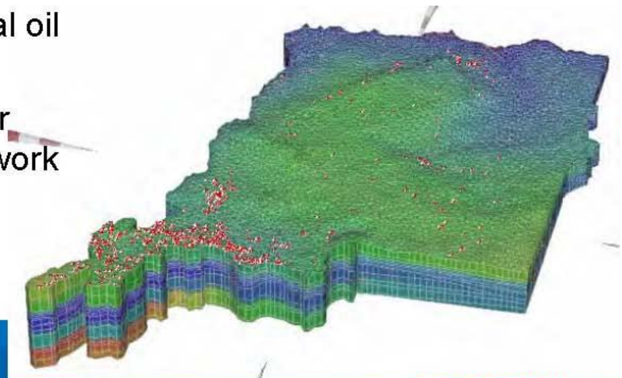
Alberta
Government of Alberta

Use of numerical modelling tools to support GMF development & implementation

Develop numerical modelling tools

- Quantify cumulative impacts from regional oil sand development
- Support groundwater management framework



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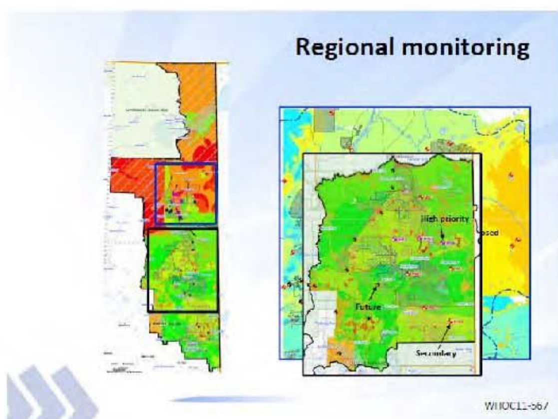
19-Mar-12

of Alberta

Regional Networks



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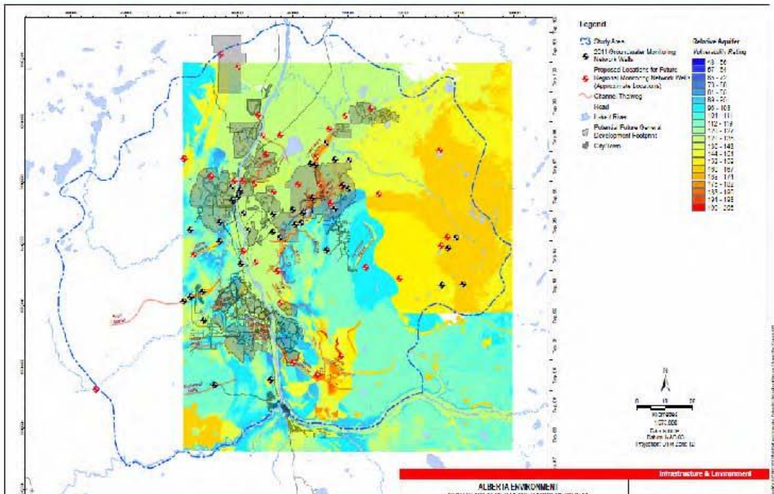
NAOS Groundwater Monitoring Network

- The current network consist of 83 wells, 50 pre-existing GOVN wells and 33 pre-existing operator-owned wells.

- The last sampling of the network was conducted in November and December 2010, and February 2011.



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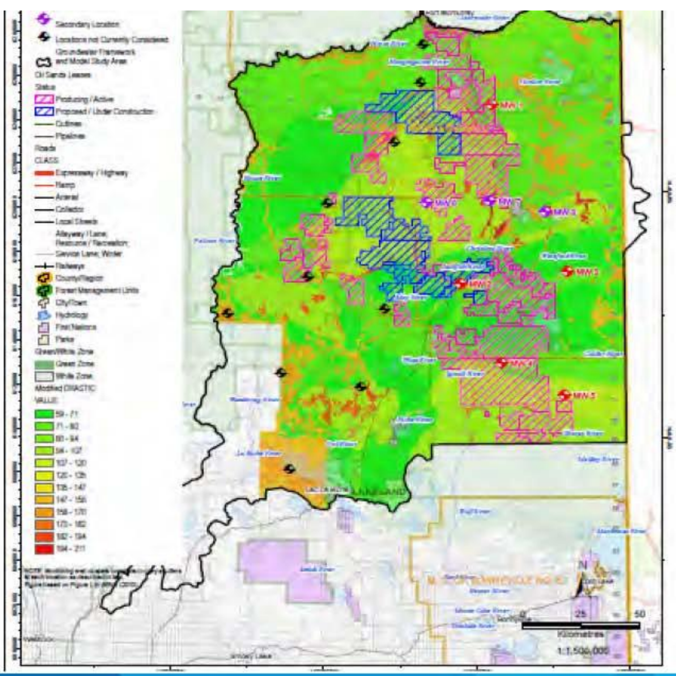
Proposed Regional Monitoring Network

Conceptual Regional GW Monitoring Network for SAOS based on modelling results includes;

5 Primary Locations
3 Secondary Locations



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SYSTEM REFINEMENTS

Through

ADAPTIVE MANAGEMENT PROCESS

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Summary

- Considerable work to date establishing regional groundwater monitoring and management in the Alberta oil sands regions
- Active networks in place *(NAOS, CLBR)* with others under development *(SAOS)*
- Draft management frameworks developed for each oil sands area *(summary document in prep.)*
- Results will be crucial in determining:
  - current state of groundwater resources *(including baseline and range of natural variability)*
  - indicator trends and future conditions
  - validity of modelled projections
  - sustainable development of groundwater resources

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Regional Groundwater Monitoring, Evaluation and Reporting (MER) Group for the AOS

- Recently Alberta Environment and Water established Regional Groundwater MER Group that will develop system to monitor non-saline groundwater resources across the Lower Athabasca Region, evaluate the data, report on the state of groundwater resources in the region, and implement regional groundwater monitoring programs in each of the three management areas (NAOS) (SAOS) (CLBR).

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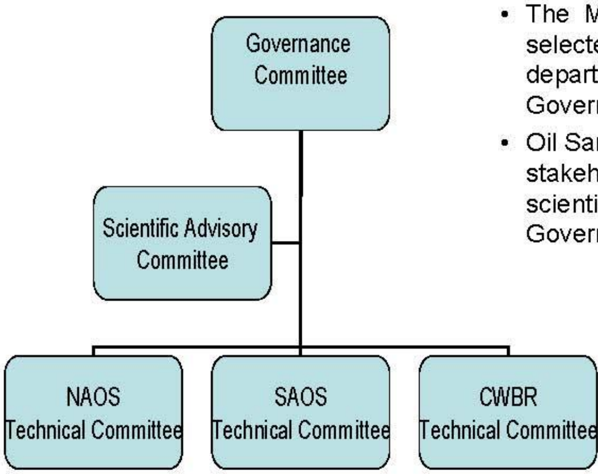
Organization

Regional Groundwater Monitoring Group for the Athabasca Oil Sands



- The MER Group is composed of selected individuals from required departments residing in the Government of Alberta,
- Oil Sands industry, other stakeholder associations, and scientists selected by the Governance Committee.

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Scientific Advisory Committee (SAC)

- Laurence R Bentley
- Carl Mendoza
- Alfonso Rivera
- Jon Paul Jones
- René Therrien
- Ben Rostron
- Edwin Cey
- Masaki Hayashi

The SAC will ensure that;

- established and proposed monitoring networks are scientifically rigorous, effective, practical and defensible;
- the groundwater monitoring plans are scientifically credible and meet current definitions of best practice;
- interpretations in reports by the TACs/Governance Committee are reviewed for credibility.

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Alberta's Current Regulatory Framework and New Directions

CEAA Workshop, 20 March 2012

Patrick Marriott, 780-427-7033

Alberta Environment & Water

pat.marriott@gov.ab.ca

Government of Alberta

Partners in Environmental Management

Key Provincial Agencies

- Environment & Water (AEW)
- Energy Resources Conservation Board (ERCB)
- Sustainable Resource Development (SRD)
- Natural Resources Conservation Board (NRCB)
- Alberta Utilities Commission (AUC)
- Health & Wellness
- Alberta Transportation

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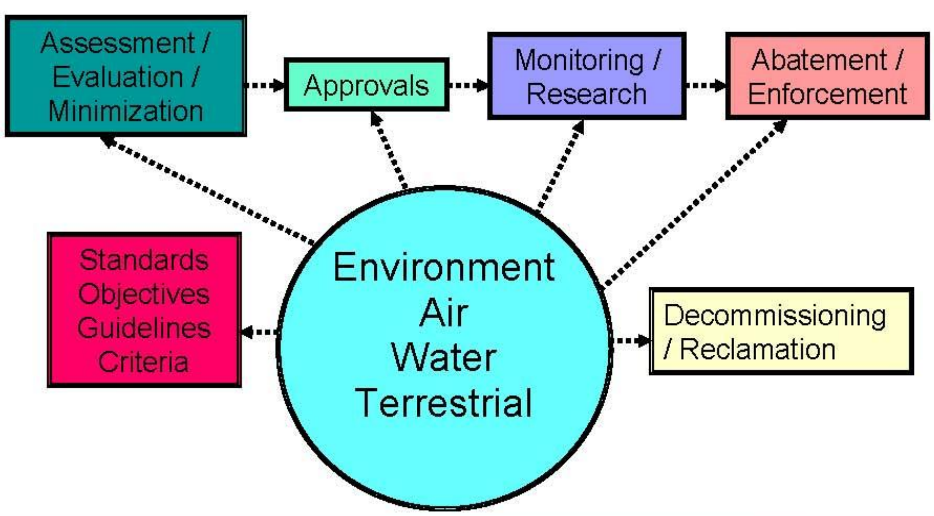
Partners in Environmental Management

Key Federal Agencies

- Canadian Environmental Assessment Agency (CEAA)
- Environment Canada
- Health Canada
- Indian and Northern Affairs Canada
- Fisheries and Oceans Canada

Overall AEW Regulatory Approach



Alberta's Environmental Assessment and Approvals Decision Making Process

EIA Process
- is an EIA needed?
- What information is needed in an EIA report?
- Is the EIA report complete?

Provincial Boards
(AUC, ERCB, NRCB)
- Is the project in the public interest?

Approvals and Allocations
- "How to" protect the environment, allocate resources? (*WA, EPEA*)

Regional Management
(*ALSA*, WPACs)
- How to achieve a sustainable environment, community and economy?

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Water Regulation-

Alberta Environment & Water

The *Environmental Protection and Enhancement Act (EPEA)*:

- Support and promote the protection of the environment
- Quality of air, land, and water → Water Quality
- Substance release, waste management, municipal water, reclamation
- *Activities Designation Regulation*

The *Water Act (WA)*:

- Quantity/Allocation → Water Quantity
- Water management

The *Alberta Land Stewardship Act (ALSA)*:

- Enables Regional Plans → Regional Monitoring and Management

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AEW Approval Process

Environmental Protection and Enhancement Act
Approvals/Authorizations

- Project life-cycle approvals, i.e. *EPEA* approvals cover construction,
- operation and reclamation (term up to 10 years, renewable)
- Single multi-media approvals, e.g. cover air and **wastewater emissions**, soil and **groundwater protection**, land conservation and reclamation, etc.

***Water Act* Approvals**
- Authorization to perform an activity in a water body
- Channel realignment for bridge, culvert
- Channel/pump to **dewater**, or drain along a grade

***Water Act* Licences**
- Authorization to divert and/or **use surface water** or **groundwater** (i.e. water allocation)
- typically a 10 year term, renewable

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Regulatory Integration - Water in the Oil and Gas Industry

AEW and ERCB Roles	
Alberta Environment & Water (AEW)	**Energy Resources Conservation Board (ERCB)**
Water Act and *Environmental Protection and Enhancement Act (EPEA)*	*Oil and Gas Conservation Act*
Water Supply	
•Water policy •Water well data •Provincial monitoring (surface and groundwater) •Water Management Plans •Water allocation- licences •Environmental Impact Assessments	•Resource evaluation (oil reserves and water resources), Alberta Geological Survey •Industry evaluation of water supply (Scheme Approval conditions) •Environmental Impact Assessment (public interest decision) •Operational policy development •Protection of non-saline aquifers
Facilities and Infrastructure (wells, pipelines, gas plants, bitumen processing)	
•EPEA facility approvals •All "downstream" facilities (refineries) •Surface waste storage facilities (3rd party) •Pipeline reclamation •All well site and plant site reclamation	•Scheme Approvals (pools, enhanced recovery, bitumen extraction, etc.) •Directives •Well licences •Pipeline approvals •Operational inspection and enforcement
Waste Management	
•EPEA reclamation at closure •Disposal policy and multi-party waste storage and disposal •Environmental Protection Orders for off-site spill cleanup	•ERCB site approvals for waste during operation •Deep well disposal (D51, etc.) •Spill reporting and management (on-site)

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New Directions

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Policy Development – Water in the Oil and Gas Industry

Water Conservation and Allocation Policy Review, 2010-2013

overall goal of policy: to reduce and eventually eliminate, on a case by case basis, the use of non-saline water

- **Phase 1** is an **Addendum** to the existing 2006 *Water Conservation Allocation* ***Guideline for Oilfield Injection*** *(2006)*. The Addendum provides guidance specific to thermal in situ bitumen extraction projects.

- **Phase 2** includes a review of performance measures for outcomes of the existing Policy and an update of the *Water Conservation and Allocation* ***Policy for Oilfield Injection*** *(2006)*. **The Policy will be expanded to apply to all oil and gas activities.**

- **Phase 3** includes updated ***Guidelines*** for specific oil and gas subsectors (water floods, thermal in situ, shale gas, bitumen mining, and CBM, etc.).

Phase 2 is underway – initial results May/June 2012

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Land Use Framework- Lower Athabasca Regional Plan (LARP)

- First and furthest advanced (currently still draft) regional plan under the *Alberta Land Stewardship Act*
  https://www.landuse.alberta.ca/RegionalPlans/LowerAthabascaRegion/PlanningProcess/Pages/DraftLARP.aspx
- Sets broad regional objectives, with further detail provided by several specific management frameworks, e.g:
  - Surface Water Quality Management Framework
  - Groundwater Management Framework
  - Air Quality Management Framework
  - *Surface Water Quantity Management Framework
- Work also underway on land access, protected areas: Two million hectares set aside for conservation areas

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LARP- Regional Outcomes

- The economic potential of the oil sands resource is optimized;
- The region's economy is diversified;
- Landscapes are managed to maintain ecosystem function and biodiversity;
- Air and water are managed to support human and ecosystem needs;
- Infrastructure development supports economic and population growth;
- The quality of life of residents is enhanced through increased opportunities for recreation and active living; and
- Inclusion of aboriginal peoples in land-use planning.

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The Single Regulator…

Based on *Enhancing Assurance* Recommendation 2:

"Establish a **single regulatory body** with unified responsibility for policy assurance (regulatory delivery) of upstream oil and gas development activities." [**+ coal**]

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Single Regulator

- Intent would be to combine all existing regulation of upstream energy sector into one agency, with its own legislation- a Government of Alberta priority

- **Single Regulator's** legislation would include the **same requirements** as listed under ***EPEA*, *Water Act*, and *Public Lands Act***, for the management of the environment, water and public lands (as applicable to upstream oil and gas and coal)

- **Government of Alberta will set policy** and will regulate all other sectors, with a **new group to coordinate policies** across different sectors and regulatory agencies

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Oil Sands Groundwater Workshop

Oil Sands Developments and Groundwater

Brenda A. Austin, P. Geol. | March 20th, 2012
Oil Sands and Coal Branch

ERCB Energy Resources Conservation Board

Alberta Regulatory Framework

Government sets policy

Legislation

↓

Other government departments → **ERCB administers policy** ← Public

Regulations

↓

Oil sands projects

3

The ERCB

The ERCB's mission is to ensure development is safe, fair, responsible, and in the public interest

Project reviews consider social, environmental and economic impacts

Requires review and understanding of data from these disciplines to understand potential impacts of projects

4

Outline

Athabasca & Cold Lake Oil Sands Areas

- Location and geology

Extraction methods

- Mining
- In situ
  - SAGD and CSS

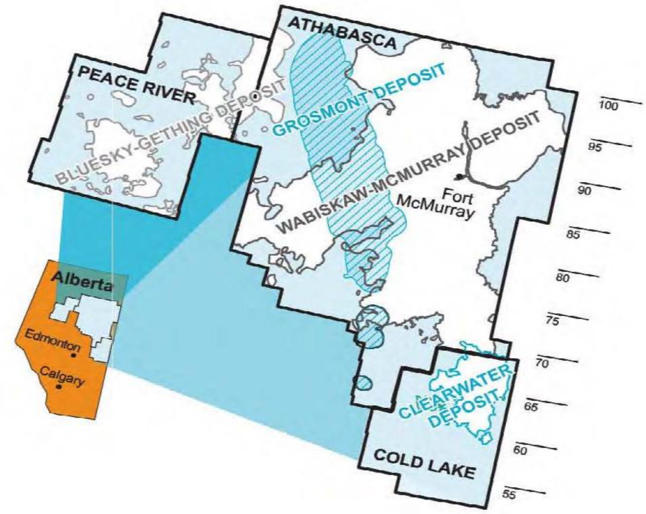
Project Reviews

- ERCB groundwater review

Surveillance

ERCB Energy Resources Conservation Board

5 Oil Sands Areas



6 Athabasca & Cold Lake Stratigraphy

PERIOD	STRATIGRAPHIC UNITS	
HOLOCENE	RECENT SEDIMENTS	
QUATERNARY	GRAND CENTRE FM	
	SAND RIVER FM	
	MARIE CREEK FM	
	ETHEL LAKE FM	
	BONNYVILLE FM	
	MURIEL LAKE FM	
	BRONSON LAKE FM	
TERTIARY	EMPRESS FM	← In situ non-saline water source
		← Pre-Quaternary Unconformity
UPPER CRETACEOUS	BELLY RIVER FM	
	LEA PARK FM	
	LABICHE FM (Colorado)	
LOWER CRETACEOUS	JOLI FOU FM	
	GRAND RAPIDS FM	← Non-saline or saline water source Limited bitumen extraction
	CLEARWATER FM	← Clearwater - bitumen zone in Cold Lake Oil Sands Area & saline/non-saline water source
	WABISKAW MBR	
	McMURRAY FM	← Wabiskaw/McMurray - in situ and mining bitumen zone in Athabasca Oil Sands Area – saline water source in some areas.
		← Pre-Cretaceous Unconformity
	Undifferentiated Devonian	

7

Extraction Processes

Mining

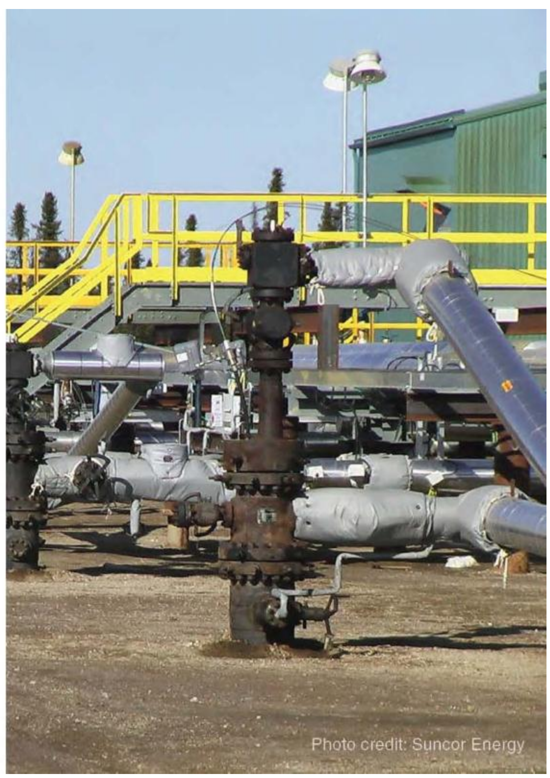
- •Shallow
  - •Physical removal of rock and bitumen – truck and shovel
  - •Fresher water required for process
    - •Process water recycled (up to 85%)
  - •Make-up water is from the Athabasca River
  - •Dewatering of Basal McMurray water prior to mining
  - •Tailing pond management – Directive 074
  - •New mines often trigger Federal involvement.

8

Extraction Processes

In Situ

- Deeper zones with caprock
- Extraction through wells by heating the reservoir
- Federal involvement not triggered to date
- Steam Assisted Gravity Drainage (SAGD)
  - • Horizontal well pairs
  - • constant steam injection
  - • lower pressures
- Cyclic Steam Stimulation (CSS)
  - • Directional or horizontal wells/ steam injected and bitumen produced through same well



Extraction Processes

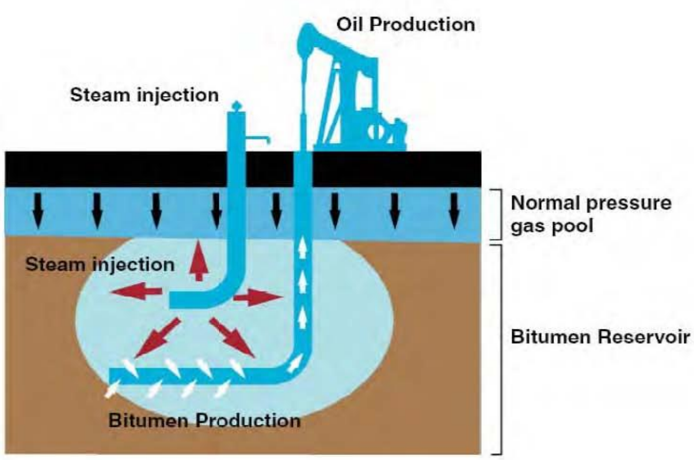
In Situ (continued)

-Other extraction technology– in development stage

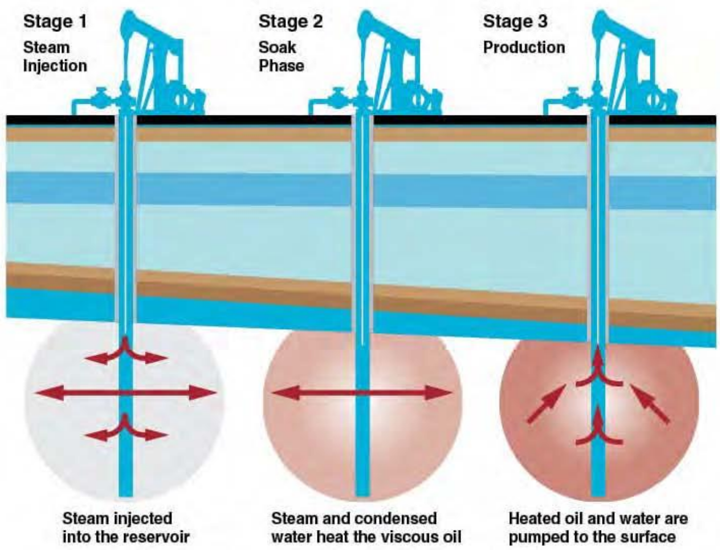
- Make-up water is generally groundwater
  - Saline/Non-saline
  - Boilers can run on higher salinity water than used in mining process
  - High recycle rate required
  - Concentrated produced fluids returned to secure sub-surface zone

10

In Situ Operations – SAGD Process



11 **In Situ Operations – CSS Process**



12 **In Situ Water Management**

New draft directive for thermal in situ oil sands schemes

Maximize produced water recycle; minimize disposal

Project Reviews

In situ schemes producing >2000 cubic metres per day of bitumen require an EIA under provincial legislation

- Joint application review process between ERCB, AEW, and other provincial ministries
- CEAA enters review if Act triggered

In situ schemes producing <2000 cubic metres per day of bitumen do not require an EIA

Project Reviews

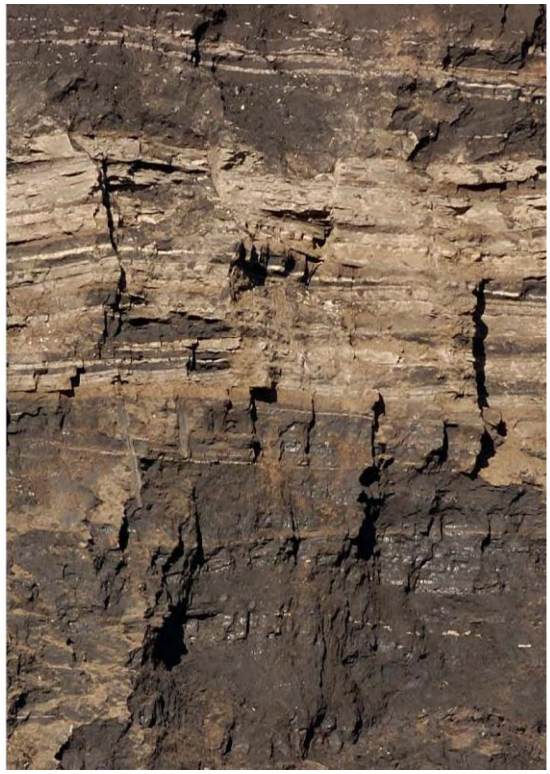
ERCB legislation requires consideration of environmental, social, and economic data

- Contained in EIA for larger projects
- In ERCB application for smaller projects (*Directive 023*)
  - Advice from other AEW or other ministries
  - AEW approvals follow

ERCB Groundwater Specific Review

ERCB staff review geological/ hydrogeological data:

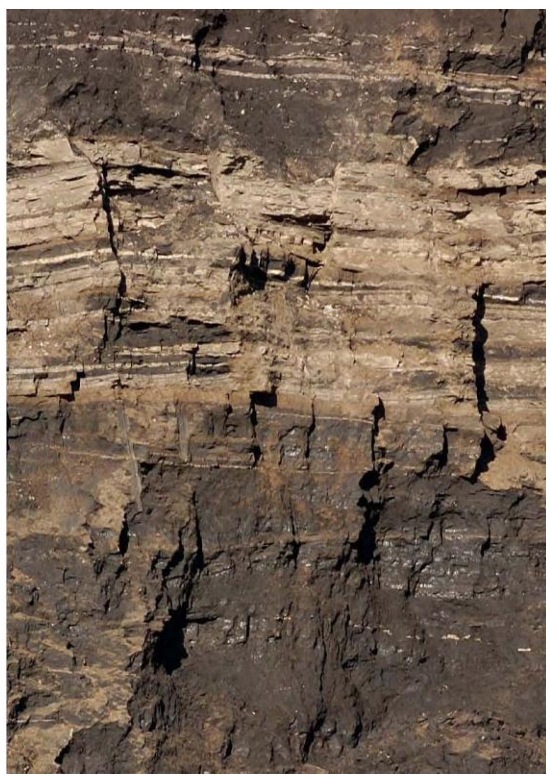
- Does the proposed project have the potential to impact groundwater?
- Has the proponent proposed appropriate mitigations?
- Changes/revisions to the project?



ERCB Groundwater Specific Review

Understanding of geology and hydrogeology important to understanding:

- GW/SW interactions
  - Bitumen outcrops
  - Saline seeps, fens, and lakes
- Water source options (Saline/Non-saline aquifers)
- Disposal zone containment (Saline aquifers)
- Reservoir extraction processes – Basal Aquifer management



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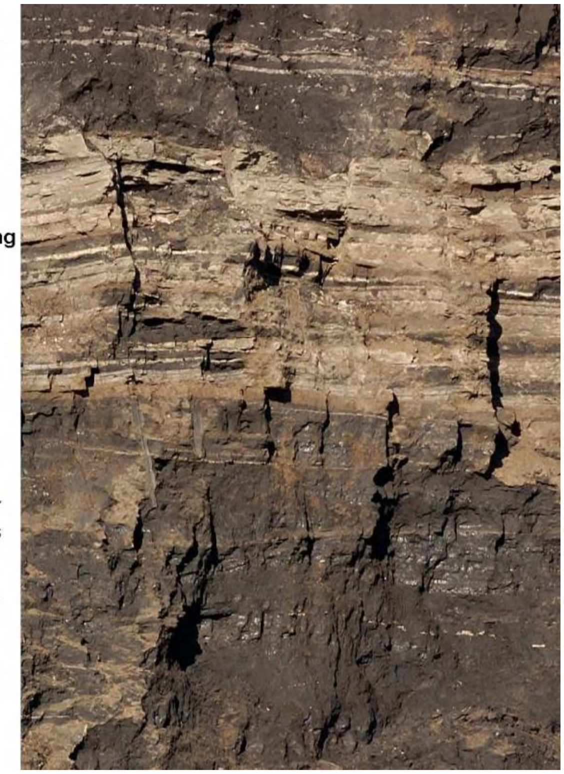
Groundwater Data Used

Geological data – understanding the container

- ERCB/AGS data and analysis, other literature sources
- Project applications/EIA's
  - Seismic, well logs, core, aquifer parameters, and monitoring well data

Hydrogeological and Reservoir data – understanding the fluids

- ERCB/AGS data and analysis
- Regional Groundwater Network data (future)
- Project applications/EIA's
  - Seismic, well logs, core, reservoir data, and monitoring well data



18

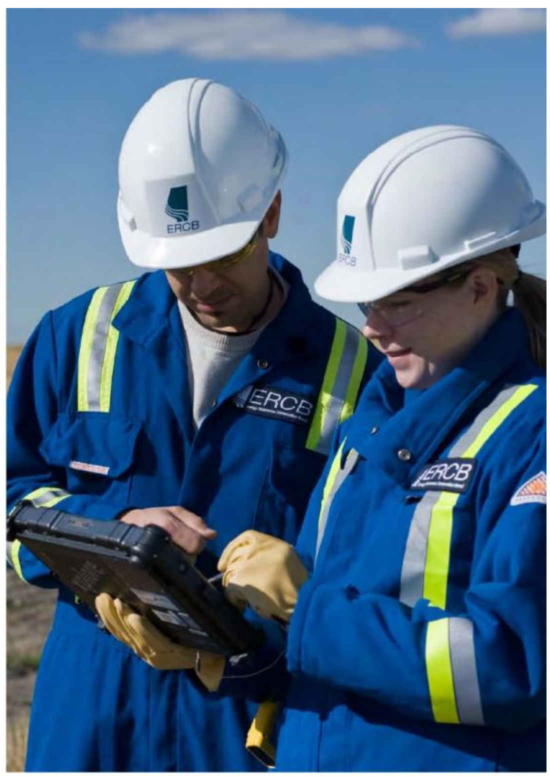
Scheme Surveillance

ERCB monitoring and reporting requirements through project life

- Reservoir containment monitoring
- Disposal zone containment monitoring
- Proponent required to apply for changes to project
- Annual performance presentations

AEW groundwater and surface water monitoring requirements associated with facilities

- AEPEA approvals



Groundwater Initiatives at the Alberta Geological Survey

Dan Palombi, Groundwater Section Leader
ERCB/Alberta Geological Survey

Oil Sands Groundwater Workshop: March 20, 2012

AGS Mission

- Official provincial survey responsible for improving and updating our knowledge of the geological framework and delivering this knowledge in the form of field observations and peer-reviewed maps and reports
- AGS Group Goal as it pertains to groundwater:
  1) Inventory the non-saline aquifers in the province and evaluate them in terms of their quantity, quality and thresholds between sustainable/unsustainable use of groundwater resources.
  2) Inventory the saline aquifers in the province and characterize them in terms of their relative value for groundwater production, aquifer storage and retrieval schemes, geothermal energy production, waste disposal, and CO_2 sequestration.
- AGS Groundwater Section creates advanced level reports and products with a specific focus on groundwater-resource inventory

ERCB | AGS

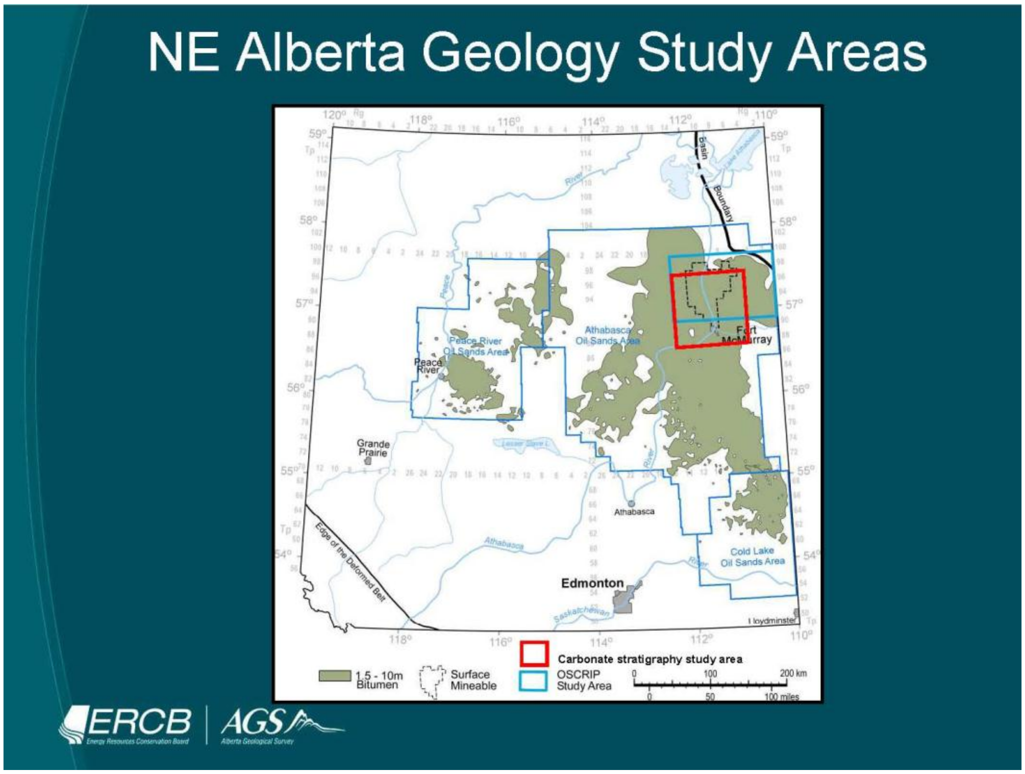
Outline

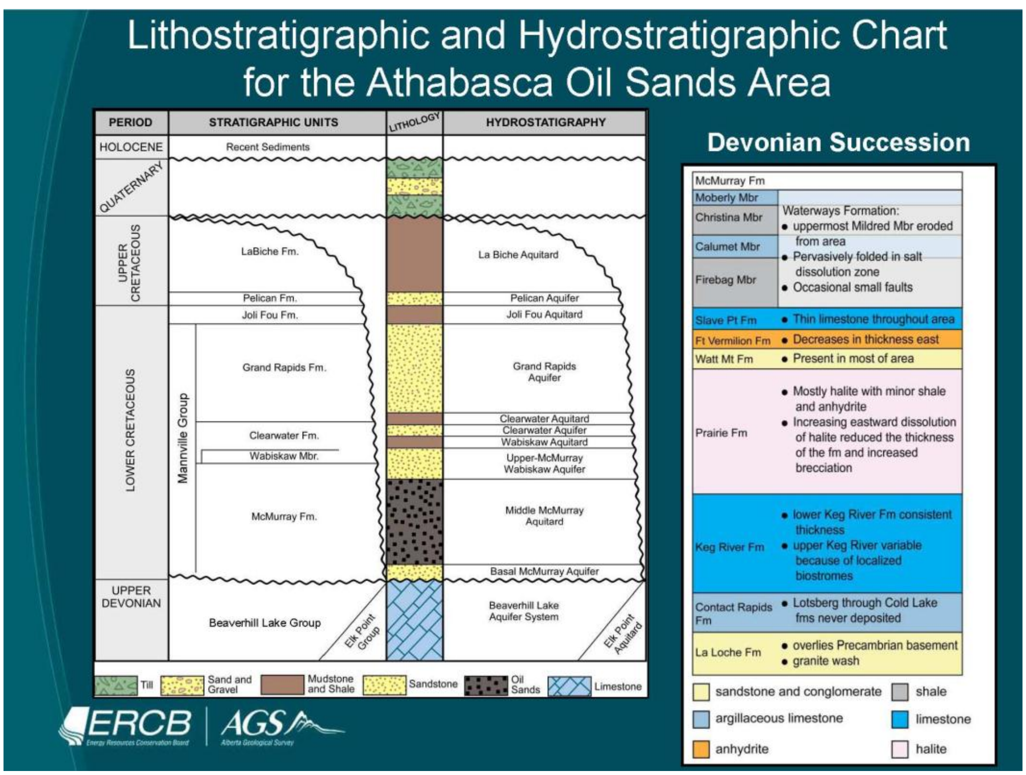
- Current AGS geology projects in NE Alberta
  - Overview of the stratigraphic column in the Athabasca oil sands area.
- Description of AGS role in groundwater management and characterization
  - Provincial Groundwater Inventory Program (PGIP)
  - Saline Aquifer Mapping Program (SAM)
- Examples of work completed, currently underway and planned with regards to groundwater mapping
- Briefly discuss areas of uncertainty and issues with respect to groundwater management and characterization

ERCB | AGS

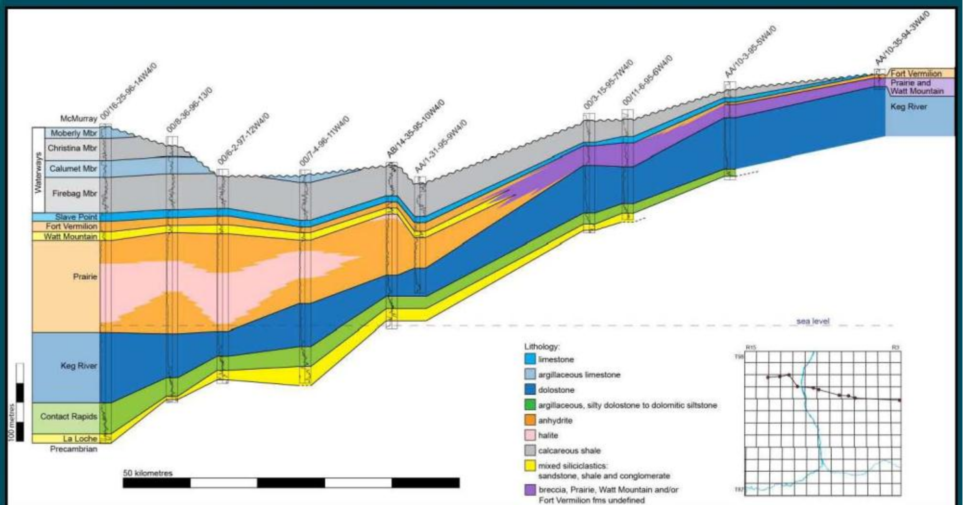
Current Geology Projects in Northeast Alberta

- Carbonate stratigraphy in NE Alberta (*Lead: Chris Schneider*)
  - High-resolution mapping of structure and karst
  - Importance of Devonian strata to oil sands operators
    - wastewater disposal, caprock integrity, Prairie halite dissolution zone
- Oil Sands Caprock Integrity Project (OSCRIP, *Lead: Kristine Haug*)
  - Undertake geological and geomechanical characterization of the units above, within and below bitumen resources in the Athabasca oil sands area to assess the geological risks related to in-situ production of bitumen
  - Understand caprock integrity issues and risks related to geological and production factors


NE Alberta Geology Study Areas
Peace River Oil Sands Area
Peace River
Athabasca Oil Sands Area
Fort McMurray
Grande Prairie
Athabasca
Edmonton
Cold Lake Oil Sands Area
Lloydminster
Edge of the Deformed Belt
Basin Boundary
1.5 - 10m Bitumen
Surface Mineable
Carbonate stratigraphy study area
OSCRIP Study Area
ERCB Energy Resources Conservation Board
AGS Alberta Geological Survey


Lithostratigraphic and Hydrostratigraphic Chart for the Athabasca Oil Sands Area
PERIOD
STRATIGRAPHIC UNITS
LITHOLOGY
HYDROSTATIGRAPHY
HOLOCENE
Recent Sediments
QUATERNARY
UPPER CRETACEOUS
LaBiche Fm.
La Biche Aquitard
Pelican Fm.
Pelican Aquifer
Joli Fou Fm.
Joli Fou Aquitard
LOWER CRETACEOUS
Mannville Group
Grand Rapids Fm.
Grand Rapids Aquifer
Clearwater Aquitard
Clearwater Fm.
Clearwater Aquifer
Wabiskaw Aquitard
Wabiskaw Mbr.
Upper-McMurray Wabiskaw Aquifer
McMurray Fm.
Middle McMurray Aquitard
Basal McMurray Aquifer
UPPER DEVONIAN
Beaverhill Lake Group
Elk Point Group
Beaverhill Lake Aquifer System
Elk Point Aquitard
Till
Sand and Gravel
Mudstone and Shale
Sandstone
Oil Sands
Limestone
Devonian Succession
McMurray Fm
Moberly Mbr
Christina Mbr
Calumet Mbr
Firebag Mbr
Waterways Formation:
• uppermost Mildred Mbr eroded from area
• Pervasively folded in salt dissolution zone
• Occasional small faults
Slave Pt Fm
• Thin limestone throughout area
Ft Vermilion Fm
• Decreases in thickness east
Watt Mt Fm
• Present in most of area
Prairie Fm
• Mostly halite with minor shale and anhydrite
• Increasing eastward dissolution of halite reduced the thickness of the fm and increased brecciation
Keg River Fm
• lower Keg River Fm consistent thickness
• upper Keg River variable because of localized biostromes
Contact Rapids Fm
• Lotsberg through Cold Lake fms never deposited
La Loche Fm
• overlies Precambrian basement
• granite wash
sandstone and conglomerate
shale
argillaceous limestone
limestone
anhydrite
halite
ERCB Energy Resources Conservation Board
AGS Alberta Geological Survey

Regional Subsurface Structure



ERCB | AGS

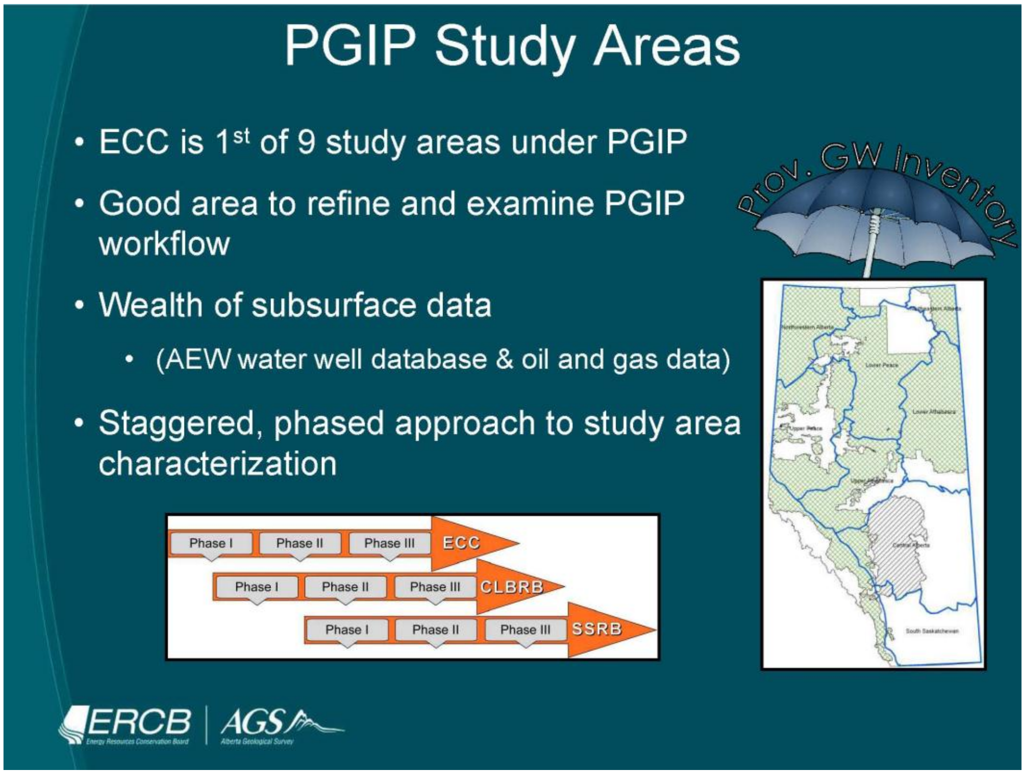
C. Schneider, ERCB/AGS

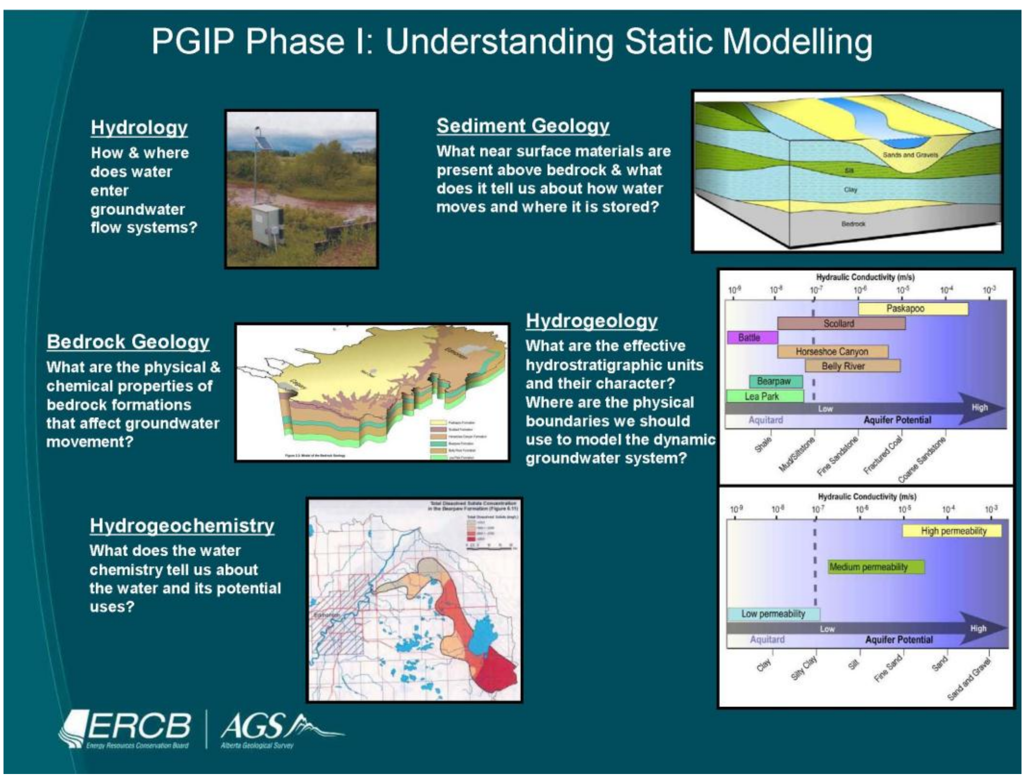
ERCB | AGS

AGS Role in Groundwater Management

Provincial Groundwater Inventory Program (PGIP)

- MOU with Alberta Environment & Water (*AGS Lead: Joe Riddell*)
- Evaluate quantity, quality, and thresholds between sustainable/unsustainable use of groundwater resources
- 3 Phases
    - I. Understand the natural system (Static Model)
    - II. Understand dynamics of GW system under development (Dynamic Model)
    - III. Develop needed tools for resource management, regulation, and policy research


PGIP Study Areas
ECC is 1st of 9 study areas under PGIP
Good area to refine and examine PGIP workflow
Wealth of subsurface data
(AEW water well database & oil and gas data)
Staggered, phased approach to study area characterization
Prov. GW Inventory
Phase I
Phase II
Phase III
ECC
Phase I
Phase II
Phase III
CLBRB
Phase I
Phase II
Phase III
SSRB
ERCB
Energy Resources Conservation Board
AGS
Alberta Geological Survey


PGIP Phase I: Understanding Static Modelling
Hydrology
How & where does water enter groundwater flow systems?
Sediment Geology
What near surface materials are present above bedrock & what does it tell us about how water moves and where it is stored?
Sands and Gravels
Silt
Clay
Bedrock
Bedrock Geology
What are the physical & chemical properties of bedrock formations that affect groundwater movement?
Hydrogeology
What are the effective hydrostratigraphic units and their character? Where are the physical boundaries we should use to model the dynamic groundwater system?
Hydraulic Conductivity (m/s)
Paskapoo
Scollard
Battle
Horseshoe Canyon
Belly River
Bearpaw
Lea Park
Low
High
Aquitard
Aquifer Potential
Shale
Mud/Siltstone
Fine Sandstone
Fractured Coal
Coarse Sandstone
Hydraulic Conductivity (m/s)
High permeability
Medium permeability
Low permeability
Low
High
Aquitard
Aquifer Potential
Clay
Silty Clay
Silt
Fine Sand
Sand
Sand and Gravel
Hydrogeochemistry
What does the water chemistry tell us about the water and its potential uses?
ERCB
Energy Resources Conservation Board
AGS
Alberta Geological Survey

ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

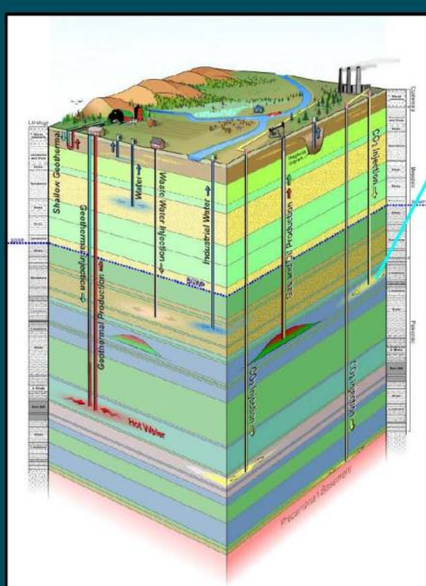
Summary of Groundwater Atlas Products

- ***Atlas*** summarizes the ECC work
- ***Open File Reports*** (Technical Detail)
  - **Geology**
  - **Hydrology**
  - **Hydrogeology (Physical and Chemical)**
  - **Modelling**
  - **Geophysics**
- ***Digital Data Sets***
  - **Surfaces**
  - **GIS files**
  - **Geophysical data**

Available from:

www.ags.gov.ab.ca

Saline Aquifer Mapping Program



Saline Aquifer Mapping Program

1. Geologic storage (CCS)
2. Future water production (shale gas)
3. Geothermal energy (industrial & domestic usage)

Characterize and assess saline aquifers for utilization

ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

Saline Aquifer Mapping Methods

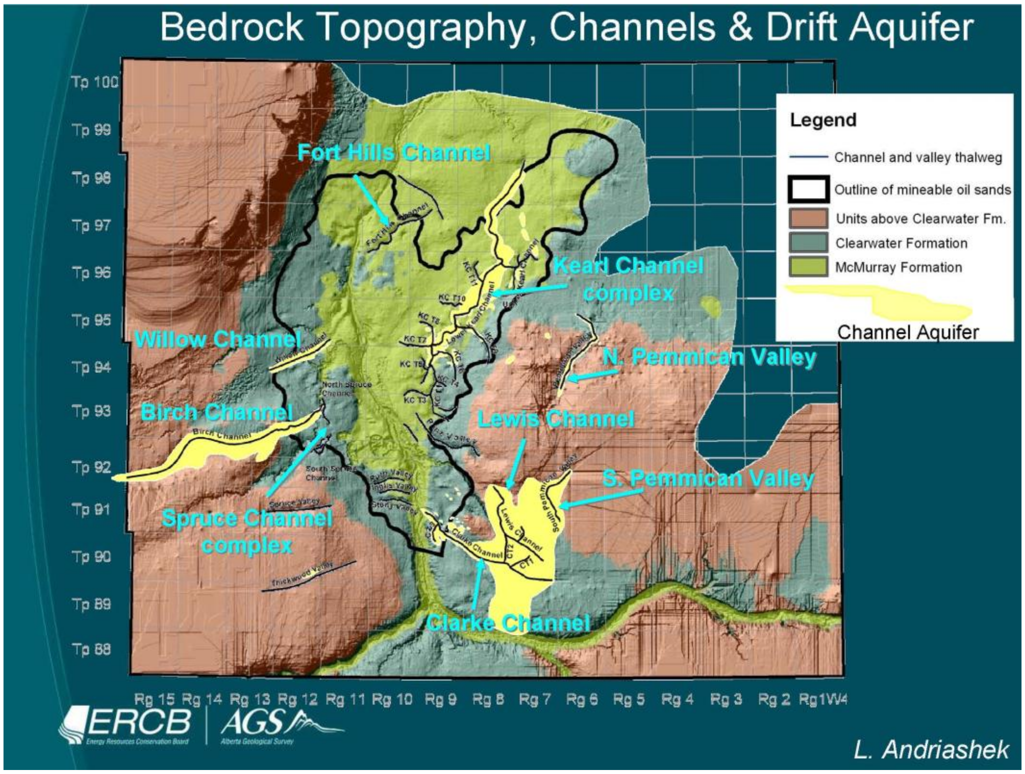
1. Hydrostratigraphy
   - Do we group or subdivide? Spatial distributions? Data processing and culling not discussed in this presentation, but critical
2. Geological mapping
   - Isopach, net sand, net porous sand and carbonate
3. 3D geological modeling
   - Build the framework for geology, property modelling and dynamic simulations
4. Distributions and patterns of salinity and hydraulic heads
   - Maps of TDS, past and present-day flow directions (gradients); Vertical gradients determined from pressure-depth profiles
5. Variable density flow effects
   - Water driving force, flow reversals, Where does density play a role?
6. Regional permeability modeling
   - Application of geostatistical methods for property modeling and aid in determination of groundwater fluxes; What about uncertainty in the estimates?

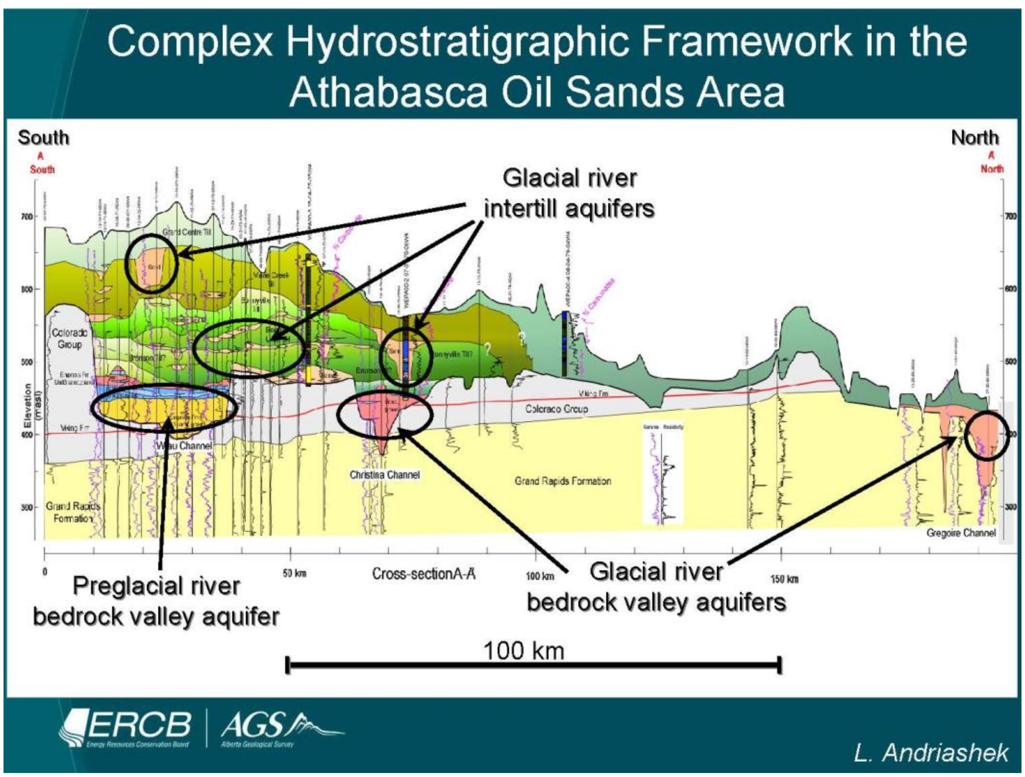
ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

Examples of Past Work in the Athabasca Oil Sands Area

- Significant amount of work completed on buried glacial tunnel channels and Quaternary aquifers in Fort McMurray area (*Lead: Laurence Andriashek*)
  - Earth Science Report 2007-01, Andriashek, L.D., Atkinson, N.
  - Geo-Note Reports 2002-01 through 11 have water chemistry data; Lemay, T.G. et al.
- Cold Lake Beaver River Drainage Basin evaluations captured in AGS Special Reports 73 and 74 focus on groundwater resource evaluations (*Lemay and Parks*)
- Fort McMurray area work focused on understanding depositional setting and mapping of buried glacial channels
  - Geological mapping included examination of outcrops and also determining the amount of incision into bedrock (channel geometry – distribution and thickness)
  - Approximately 37,000 new borehole data acquired in 2005 by industry
  - Issues identified include:
    1) deeply entrenched tunnel channels that incise into McMurray oil sand (up to ~150m of channel fill
    2) channels located directly above salt dissolution collapse zones
    3) potential steam chamber breakthrough into channel deposits


Bedrock Topography, Channels & Drift Aquifer
Legend
Channel and valley thalweg
Outline of mineable oil sands
Units above Clearwater Fm.
Clearwater Formation
McMurray Formation
Channel Aquifer
Fort Hills Channel
Kearl Channel complex
Willow Channel
N. Pemmican Valley
Birch Channel
Lewis Channel
S. Pemmican Valley
Spruce Channel complex
Clarke Channel
Tp 100
Tp 99
Tp 98
Tp 97
Tp 96
Tp 95
Tp 94
Tp 93
Tp 92
Tp 91
Tp 90
Tp 89
Tp 88
Rg 15 Rg 14 Rg 13 Rg 12 Rg 11 Rg 10 Rg 9 Rg 8 Rg 7 Rg 6 Rg 5 Rg 4 Rg 3 Rg 2 Rg1W4
ERCB
AGS
L. Andriashek


Complex Hydrostratigraphic Framework in the Athabasca Oil Sands Area
South
North
Glacial river intertill aquifers
Preglacial river bedrock valley aquifer
Glacial river bedrock valley aquifers
Colorado Group
Wau Channel
Christina Channel
Grand Rapids Formation
Gregoire Channel
Cross-section A-A
100 km
ERCB
AGS
L. Andriashek

ERCB | AGS

Geology Summary

- AGS is currently working on geological characterizations in the Athabasca Oil Sands area:
  - Carbonate Stratigraphy & Oil Sands Caprock Integrity Project (OSCRIP)
    - High-resolution mapping of structure and karst
    - Importance of Devonian strata to oil sands operators
    - Issues to address: wastewater disposal, caprock integrity, Prairie halite dissolution zones (collapse features), geomechanical considerations

ERCB | AGS

Groundwater Summary

- Groundwater Section is currently working on the Provincial Groundwater Inventory Program (PGIP) and Saline Aquifer Mapping Program (SAM)
  - Evaluate quantity, quality, and thresholds between sustainable/unsustainable use of groundwater resources
  - Develop groundwater models with the intent of aiding management, regulation and policy decisions
  - Characterize and assess saline aquifers for potential utilization
  - Issues to address: Scale of investigation for characterization and numerical models, lack of long term monitoring data at the sub-basin scale to inform transient models, development of high resolution geological models, manpower

- Significant work completed and published on glacial geology and hydrogeology in northeast Alberta (Fort McMurray area and Cold Lake Beaver River Basin)

Environment Canada Environnement Canada

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Groundwater Monitoring in the Lower Athabasca

Overview of Activities & Groundwater Strategy for the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring

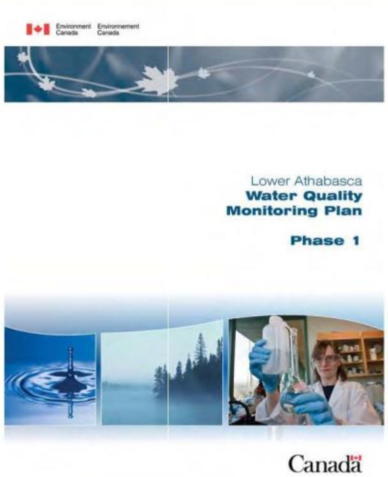
Greg Bickerton

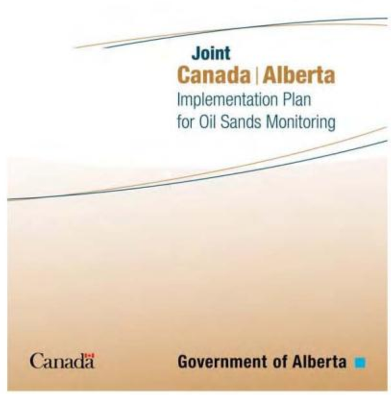
Senior Hydrogeologist

Groundwater Section, National Water Research Institute

Environment Canada, Burlington, ON

Framework Documents





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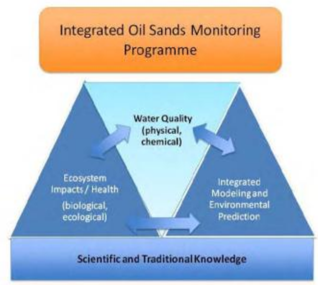
Key Concepts of Monitoring Plan

- Integrated ecosystem-based
- Mass-balance approach
- Cumulative effects assessment
- Adaptable management
- Transparent & Accessible
- Scientifically credible
- Peer-reviewed



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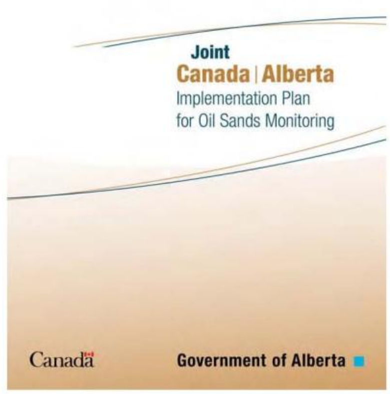
Components of Implementation Plan

- Air Quality
- Acid Sensitive Lakes
- Aerial Deposition
- **Water Quality/Quantity**
- Aquatic Ecosystem Health
- Wildlife Toxicology
- Terrestrial Biodiversity
- Data Management



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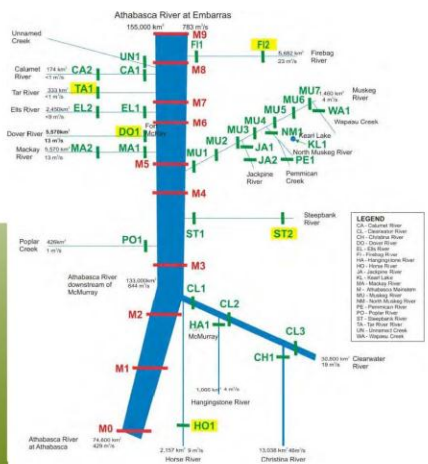
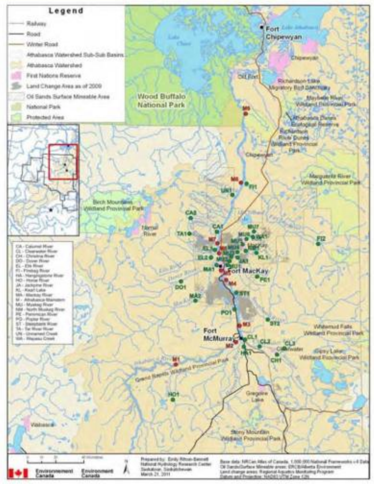
Initial Geographic Scope





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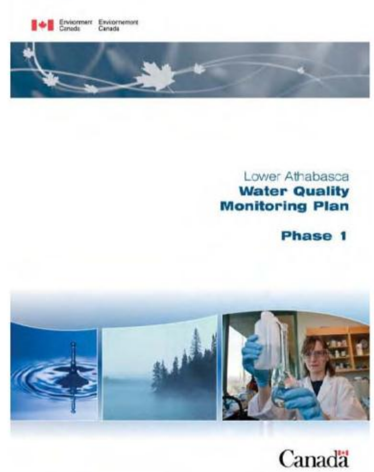
Groundwater Component

- Ecological focus on groundwater-surface interactions
- Relative importance & contribution of groundwater quality and quantity to surface waters
- Assessment of nature & extent of seepage from tailings facilities to surface water
- Characterization of ambient groundwater conditions & natural variability



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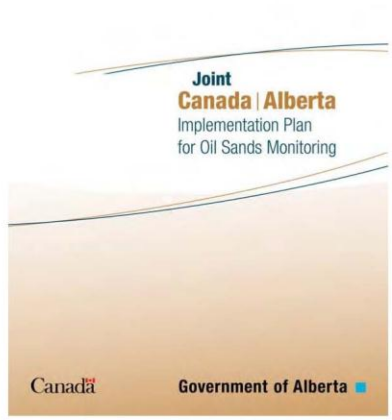
Groundwater Highlights

Water Monitoring

- NEW - Intensive monitoring of sources of potential near-surface groundwater contaminants & pathways
- NEW - Integrated & intensive scientific investigations on representative watersheds



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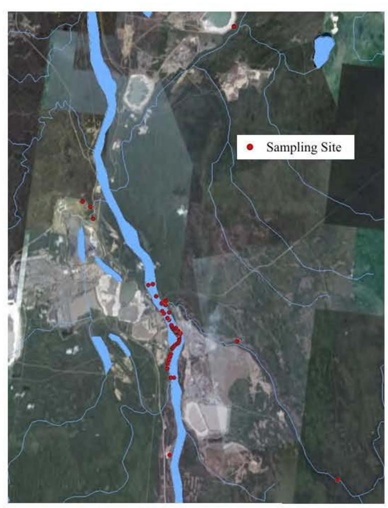
Groundwater Activities (2009-2011)

- Preliminary assessment of process-affected water in shallow groundwater discharging near tailings facilities
  - Approximately 200 groundwater quality samples collected
  - Focus on Tar Island Dyke/Suncor Pond 1



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Groundwater Focus
Joint Monitoring Plan

Ecosystem-based approach on identifying & understanding the groundwater effects of the oil sands industry on the river systems in the region.

Proposed Next Steps
Joint Monitoring Plan (2012-2015)

- Screen tributaries for groundwater discharge using isotopic & geochemical indicators
- Map groundwater discharge & quantify groundwater fluxes in locations identified in screening
- Monitoring groundwater quality from areas identified in discharge mapping

Coordination with Government of Alberta

Over the next 3 years the Governments of Canada and Alberta will be coordinating & integrating their groundwater monitoring activities for the oil sands region under the Joint Monitoring Plan

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Linkages with Government of Alberta's
LARP Groundwater Management Framework

- Common elements in monitoring philosophy
- Examples of potential linkages
  - Northern Athabasca Oil Sands Area modeling & monitoring
  - Groundwater surface-water interactions
  - Establishing baseline groundwater conditions & natural variability at regional scale
  - Monitoring data from operators approvals
  - Data integration

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Joint Monitoring Plan
Legislative & EA Context

- Designed to inform pertinent legislation, regulatory actions
- Key questions addressed
  - Are there changes in ecosystem conditions?
  - Which contaminants are entering ecosystem from oil sands operations?
  - Can contaminant types & loads be attributed to specific sources?
  - Are substances added to river natural or anthropogenic?

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Fisheries and Oceans Canada | Pêches et Océans Canada

DFO and Groundwater – Surface Water Interactions

Fisheries and Oceans Canada Prairies Area | Pêches et Océans Canada Région des Prairies

Court Berryman
Fisheries and Oceans Canada
March 2012

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Outline:

- DFO – who we are and what we do
- Oil Sands development:
  - Primary Issues of GW-SW Interaction
    - Open Pit
    - SAGD
- The Review Process
- A Brief Example
- Next Steps
- References

Fisheries and Oceans Canada — Pêches et Océans Canada

Who we are and what we do

- Fisheries and Oceans Canada (DFO) is responsible for administering the *Fisheries Act* throughout Canada
- Utilize the Habitat Protection Provisions of the Fisheries Act:
  - Section 35 - Prohibits Harmful Alteration, Disruption or Destruction (HADD) of fish habitat.
  - Section 36 - Prohibits the deposit of a deleterious substance into waters frequented by fish. (administered by Environment Canada)

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Who we are and what we do

Fisheries Act Definitions

- *Fish:* all life stages of fish, shellfish, crustaceans and marine animals
- *Fish Habitat:* any areas that fish depend on during their life-cycle (spawning, nursery, rearing, migration, food supply)

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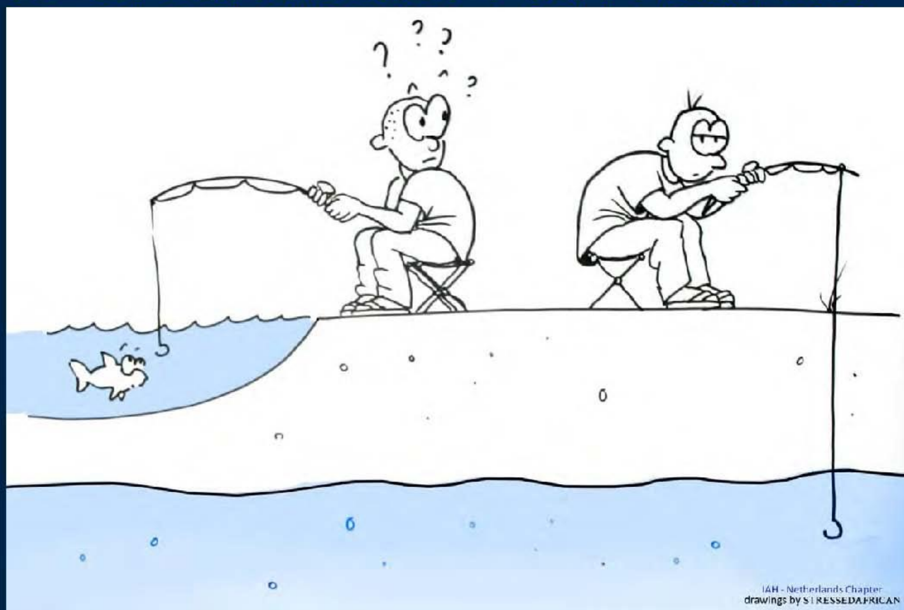
Is Groundwater Fish Habitat?



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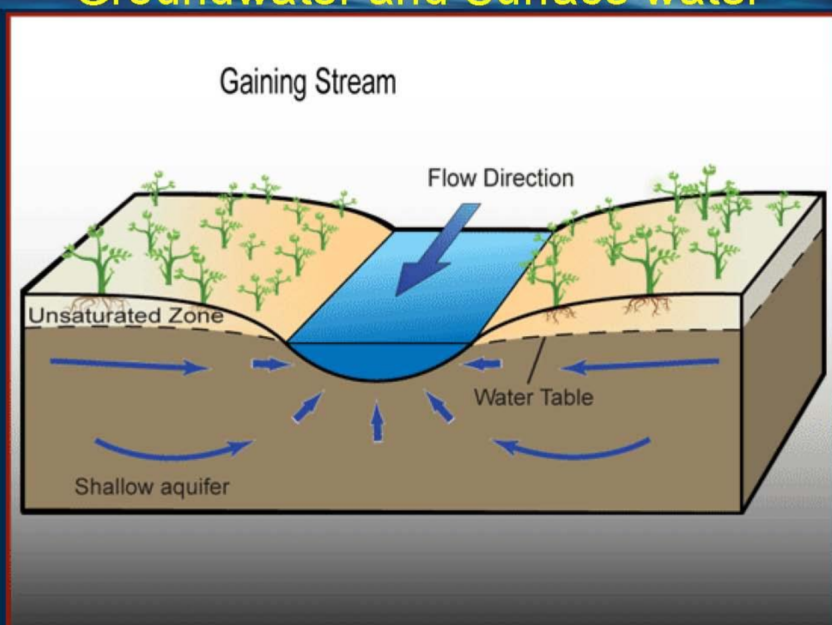
Groundwater and Surface water



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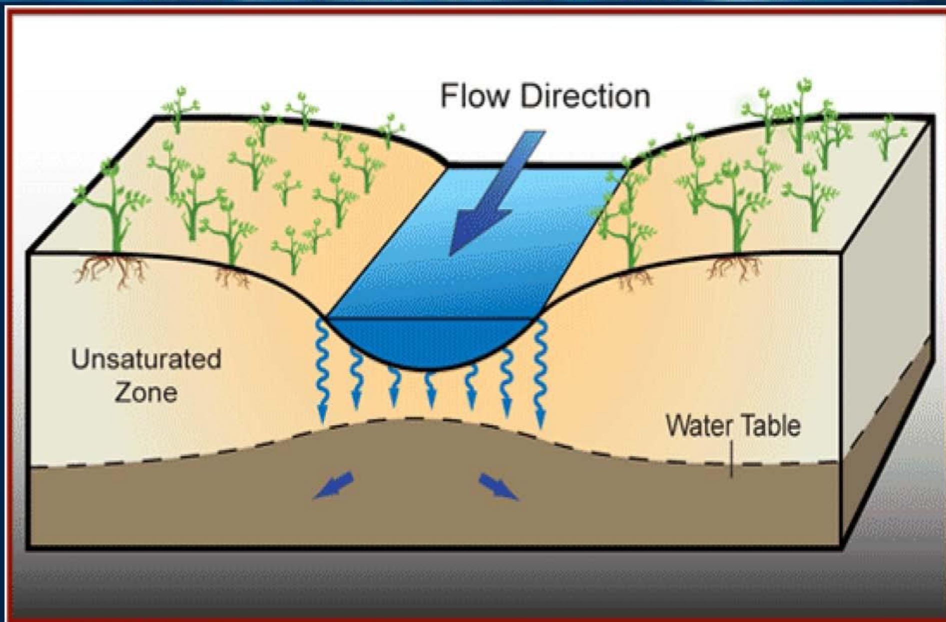
Groundwater and Surface water



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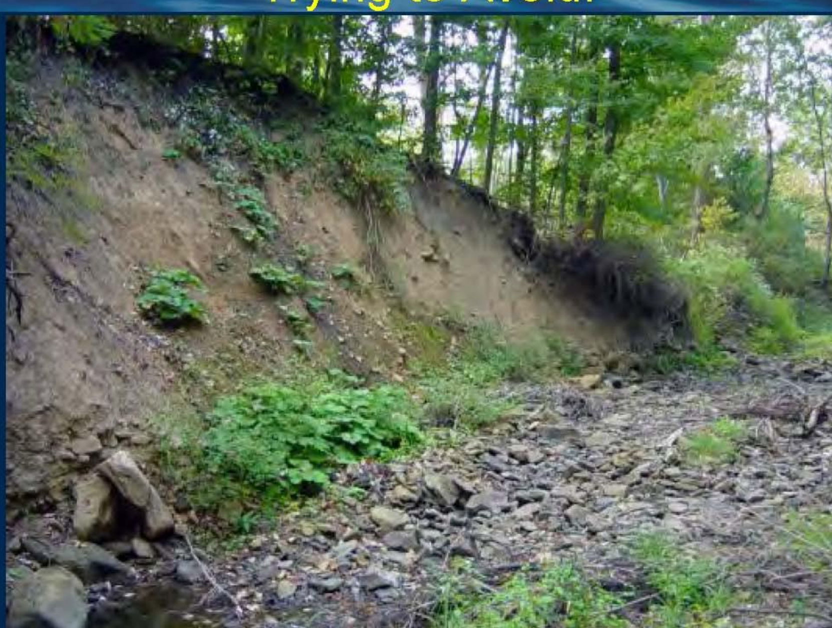
Trying to Avoid:



Primary Issues of GW-SW Interaction

Open Pit Mines

- Aquifer depressurization required to ensure safe and efficient operations:
  - Water pumped from aquifer to lower hydraulic head (pressure) around active pits.
  - Potential for reduction of groundwater baseflow to surface waters.

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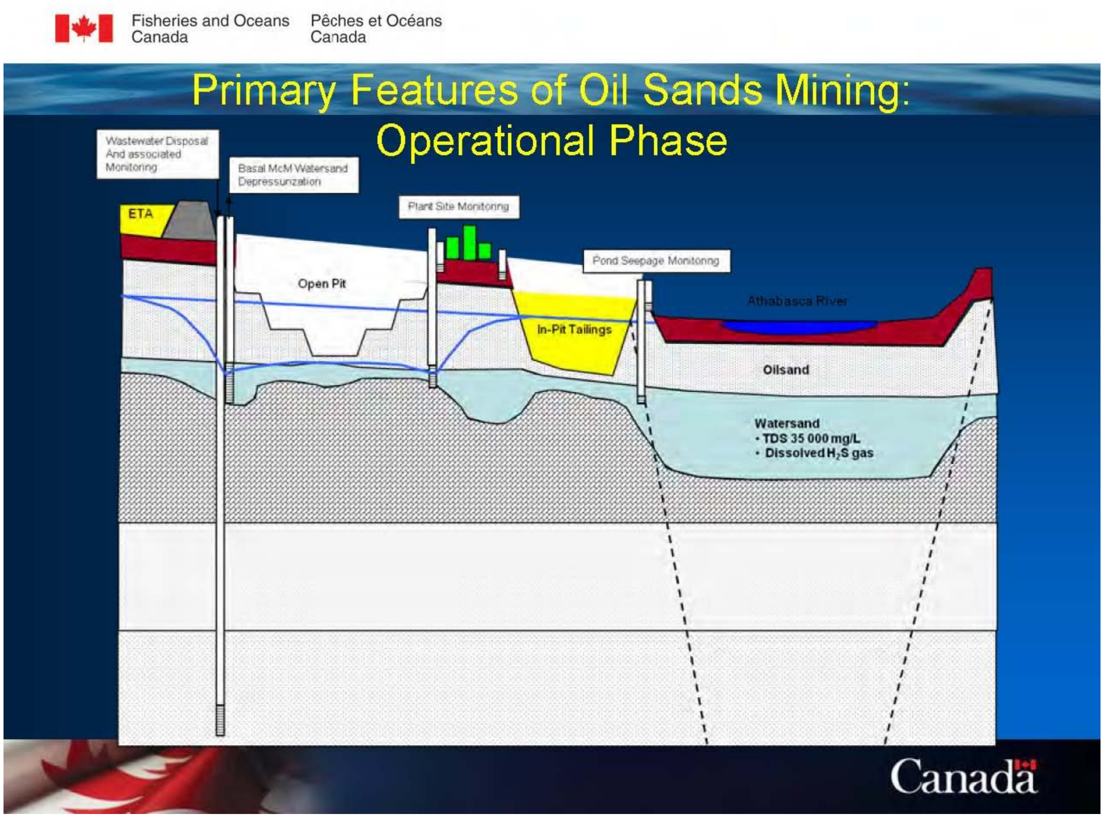
Fisheries and Oceans Canada
Pêches et Océans Canada
Primary Features of Oil Sands Mining:
Operational Phase
Wastewater Disposal
And associated
Monitoring
Basal McM Watersand
Depressurization
Plant Site Monitoring
Pond Seepage Monitoring
ETA
Open Pit
Athabasca River
In-Pit Tailings
Oilsand
Watersand
• TDS 35 000 mg/L
• Dissolved H_2S gas
Canada


SAGD

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Primary Issues of GW-SW Interaction SAGD

- Induced recharge from water supply operations:
  - Pumping from aquifers will lower the hydraulic head.
  - Lower heads will result in a greater head differential and therefore greater leakage.
  - Integrity and heterogeneity of overlying confining beds.
  - Potential for reduction of groundwater baseflow to surface waters.

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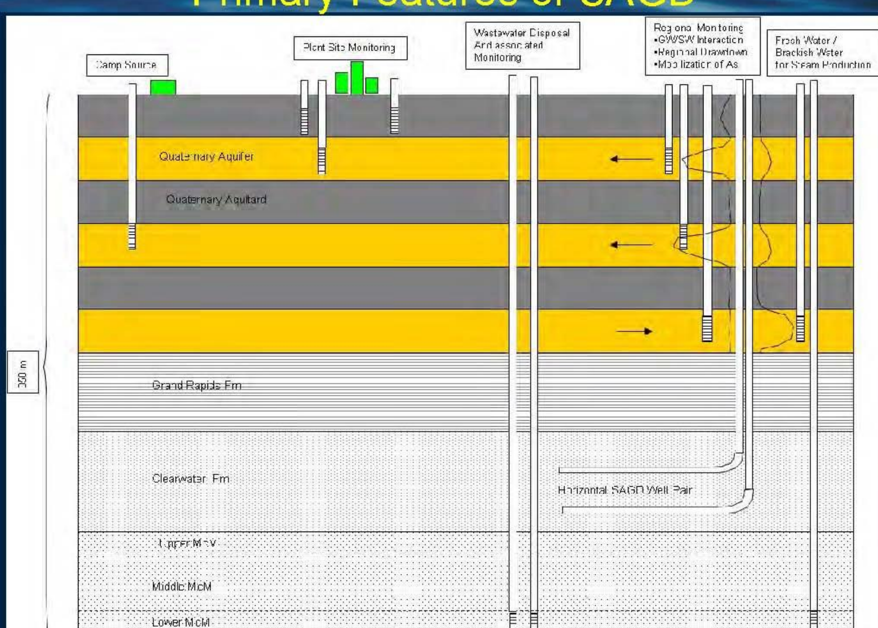
Primary Features of SAGD



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The Review Process – What is Important?

- Challenges of Establishing Sub-Surface Baseline Conditions:
  - Statistical significance
  - Narrow window of time
  - Seasonal variation
  - Local anomolies
  - Sampling parameters

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The Review Process – What is Important?

- Challenges of Identifying linkages between groundwater and surface water:
  - Identifying the sub-surface hydraulic connections of groundwater to surface water.
  - Getting a monitoring network in place and the data collected prior to groundwater impacts having occurred.

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A Brief Example…Dover OPCO 2010

- "Drawdown in the near surface water table due to Project-related groundwater withdrawal from the Grand Rapids formation and the Empress Birch Channel Aquifer was found to potentially affect surface water flows (Dover OPCO 2010, Volume 4, Sec 5),…Reduced groundwater discharge to surface water can result in reduced instream flows that typically have minimal hydrologic effects during average or high flow conditions, but may have hydrologic consequences during low flow periods".

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A Brief Example…Dover OPCO 2010

- For the full development, the % decrease in groundwater discharge to surface waters along the given reach is:
  - 8% for the Dover River (98 km reach),
  - 9% for the Ells River (99 km reach),
  - and 14% for the Dunkirk River (57 km reach) (EIS, Volume 4, Table 5.5-2).
  - The potential of slightly less than a 5% reduction in 7Q10 flows in the lower MacKay River.

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A Brief Example…Dover OPCO 2010

- Uncertainties can be associated with the modelling and measurement of low flows:
  - Measurement errors;
  - The relative contribution of GW discharge to low surface flow;
  - The groundwater model….**the level of uncertainty in such a relatively complicated hydrogeologic system is high**……. Until then, the model is a useful but **rather broad guide to potentially subtle interfaces, such as zones of groundwater/ surface water interchange.** (Dover OPCO EIA, Vol 4, Sec 2, pp 2-17).

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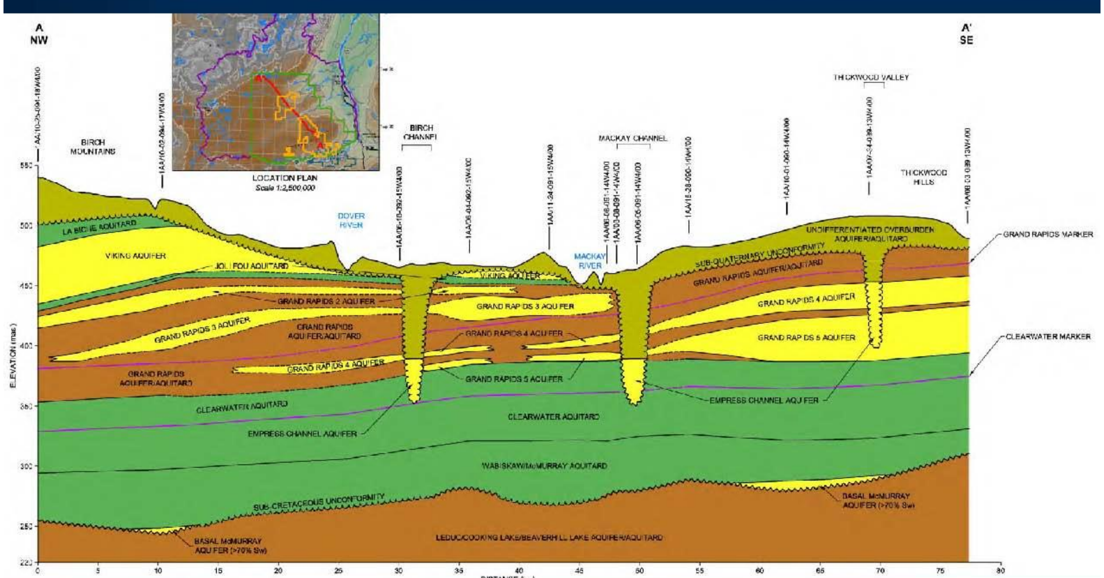

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A Brief Example…Dover OPCO 2010

- Limited Baseline Data…….”the document (baseline - hydrogeology) appears to be a compilation of data from the literature rather than from on-site data collected by the proponent”
- There appears to be very limited on-site information on the groundwater flow directions, velocity and chemistry. This baseline information is crucial for understanding how the proposed Project may affect baseline conditions. Baseline information is generally collected prior to commencement of the Project. The Proponent is proposing to collect this information after project approval (*NRCan comments - Dover In Situ Project, April 2011).*

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A Brief Example…Dover OPCO 2010

Review Results:

- DFO did not trigger based on the uncertainty around the degree of potential impacts to fish habitat.
- Difficult to verify Environmental Assessment predictions.
- DFO communicated our uncertainty with respect to potential impacts to fish habitat and the proponent has agreed to implement some monitoring.

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The Review Process: Possible Next Steps

- Areas requiring greater understanding:
  - Identify sensitive areas from a fish habitat perspective and build a GW understanding around those areas.
  - Identify sensitive groundwater resources and their upstream interaction with industry and downstream interaction with surface water.
  - Cumulative effects.

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References:

- Golder 2011; Golder – DFO Groundwater –Surface Water Meeting Presentations; July 26, 2011.
- Dover OPCO Project Application for Approval 2010; Dover OPCO Additional Information Request March 2011;
- NRCan Project Specific Review:
  - Dover OPCO
- Google Images

Canada

Groundwater Monitoring in the LAR:
Panel Conclusions and What's Next

Oil Sands Groundwater Workshop
March 20, 2012
Edmonton, Alberta

Alberta WaterSMART

CEMA Project Description

Project Objective:

Develop recommendations for implementation of the findings of recent federal and provincial panels and of the recently drafted LARP GWMF.

Project Work: (August – December 2011)

- Recent federal and provincial panel reports and LARP GWMF reviewed and summarized.
- Interviews conducted with stakeholders and Aboriginal groups to identify any new issues not addressed in the panel reports or LARP GWMF.
- Current activities in LAR summarized, based on WorleyParsons study.
- Recommendations developed to address gaps identified.
- Recommendations provided to CEMA on how to address the panel findings and the LARP GWMF, focusing on policy recommendations.

Documents Reviewed

Panel Reports and Frameworks

- Royal Society of Canada
- Federal Oil Sands Monitoring Panel (plus Phase 1 and 2 documents)
- Alberta Environmental Monitoring Panel
- Provincial Water Monitoring Review Panel
- LARP GWMF
  - Phase 1 – Technical Summary
  - Phase 2 – Program Summary

Other Reports & Reviews

- RAMP Review Panel
- Water Matters Reports
  - *"Replacing the Oil Sands' Regional Aquatic Monitoring Program with Effective Environmental Monitoring Solutions"*.
  - "Drilling Down: Groundwater Risks Imposed by In-situ Oil Sands Development"
- Federal Auditor's Report (Assessing Cumulative Environmental Effects of Oil Sands Projects)

Panel Reports and LARP GWMF Highlight Need for:

Monitoring and management based on science, independently verified

A regional monitoring program

Regional groundwater characterization, including non-saline and saline aquifers

Establishing a baseline for groundwater monitoring

Better understanding of surface and groundwater connectivity

Leadership!

An Implementation Plan to show how all the elements of the system will be linked together

Addressing real or perceived impacts of oil sands development

Considering regional water quantity as well as quality

A regulatory framework for groundwater that allows for proactive management of the resource

A monitoring and management system that is properly and sustainably resourced

Transparency in science and communication

Consistent Perspectives from Participant Interviews

Monitoring

- Understanding that **compliance-level monitoring** was undertaken as a condition of a Water Act and/or an EPEA approval.
- Concern expressed that monitoring information does not have significant importance, because it is not gathered upfront and used to **inform regulators** whether a proposed development should be approved or not.
- Shared perspective that a **monitoring gap exists at the regional level**.

Reporting and Data Management

- Shared perspective that considerable **gaps exist in the groundwater reporting framework**.
- Overwhelmingly, interviewees expressed a need for improved **transparency** in the system.
- Majority believe that a body sitting at the **regional level**, looking at all the data, assessing trends, and using this data to inform management decisions, etc. is missing in the current framework.

What's New in 2012

Government of Alberta

News release

Alberta

March 13, 2012

Experts begin work on designing improved provincial environmental monitoring system

Group will focus on governance and funding issues

Edmonton... The Government of Alberta has named a group of experts to provide detailed advice on establishing a province-wide comprehensive environmental monitoring system.

"Our goal is to build a world-class, science-based monitoring system," said Diana McQueen, Minister of Environment and Water. "This team of scientific, regulatory and academic experts will review governance and funding options and provide recommendations to the government so that we continue making progress."

The working group will focus on developing an implementation plan based on previous recommendations from the Alberta Environmental Monitoring Panel: establishing a system with appropriate transparency and scientific oversight to carry out environmental monitoring, evaluation, and reporting functions; and providing a dedicated, stable revenue stream to fund monitoring, evaluation, and reporting activities across the province.

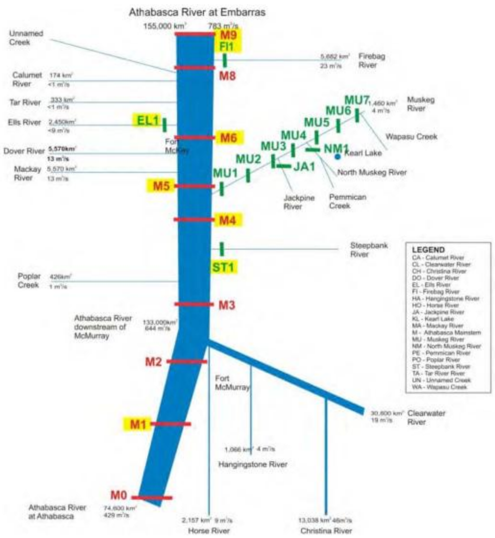
"Although the Alberta government set aside $11 million in Budget 2012 for monitoring, the estimated cost for a cumulative effects monitoring system is significantly higher," added McQueen. "The working group will consider what structures need to be in place to ensure a dedicated revenue stream and they will look at the number of organizations that currently play a role in environmental monitoring and consider the best ways to integrate and further this work."

Leading the six-member working group is Howard Tennant, the former president and vice-chancellor of the University of Lethbridge. Tennant was also a co-chair of the Alberta Environmental Monitoring Panel, which provided 20 recommendations to government in July 2011 on building a world-class monitoring system.

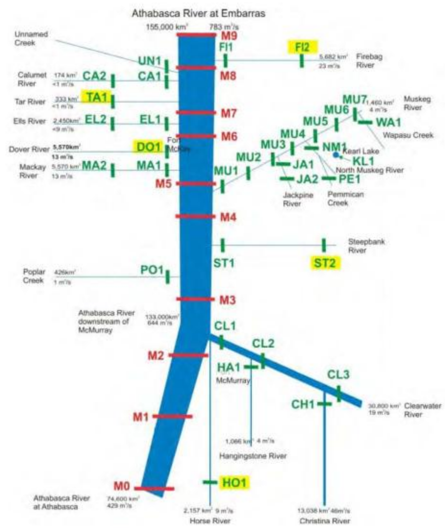
Joint Canada Alberta Implementation Plan for Oil Sands Monitoring (Phase 3)

Alberta WaterSMART

Key Sampling Locations 2011 - 2012



Key Sampling Locations 2015 projected



Key Groundwater Gaps Still Need to Be Addressed

Alberta WaterSMART

Phase 3 Implementation Plan	Mandate of Alberta Panel	GAPS
✓ Leadership ✓ Monitoring and management based on science, independently verified ✓ A regional monitoring program ✓ Addressing real or perceived impacts of oil sands development	❖ A regulatory framework for groundwater that allows for proactive management of the resource ❖ A monitoring and management system that is properly and sustainably resourced ❖ Transparency in science and communication	Regional groundwater characterization, including non-saline and saline aquifers Consider regional water quantity as well as quality Better understanding of surface and groundwater connectivity Establishing a baseline for groundwater monitoring

An Implementation Plan
to show how all the elements of the system will be linked together

Additional Observations: My thoughts Only

Feds:
- Politically driven agenda
- Drive to identify and fine violators
- Get ‘Boots on the Ground’ in 2012

Alberta:
- Need to manage the resource
- Drive to manage regional cumulative effects
- Need to complete the GWMF

Industry:
- Okay that increased regional monitoring program is moving forward
- Drive to better characterize groundwater resources
- Need to understand funding of monitoring program

Stakeholders:
- Need for independent and transparent disclosure
- Drive to better understand cumulative impacts
- Unsure of ‘teeth’ of new monitoring and regulatory systems

Project Summary: SW-GW Interaction in the Lower Athabasca Region (L.A.R.)

Jon Paul "JP" Jones, Jean Birks and John Gibson

General Scope of the Project

- Present a general overview of the issues in the L.A.R. in the context of SW-GW Interaction
  - What is known currently
  - Types of impacts
  - Monitoring Framework
- Summary of available tools and techniques for quantifying SW-GW Interaction
- Ongoing SW-GW interaction activities in the L.A.R.
- The proposed work plan for moving forward has two themes:
  - Characterization
  - Prediction

Currently

- Studies at the Utikuma Research Study Area (URSA) and Lac La Biche site
  - GW-lake interaction studies
  - GW-wetland interaction studies
    - Wetlands span ~50% of L.A.R.'s landscape and therefore are an important type of SW-GW interaction for region
    - It is an open question as to how translatable the findings of these studies will be to the more wetland dominated watersheds in the LAR.
- Work by the CEMA IFNTTG:
  - Consensus that GW contributions to the Athabasca River are small in comparison to annual flows
  - No clear understanding of GW contributions in terms of flow or quantity
  - Implications?

Currently

- Water balance studies at Lakes
  - Radon-222 studies at two wetland dominated watersheds (Schmidt et al., 2010) have estimated GW contributions to lakes
  - Isotope mass balance studies at the 50 RAMP lakes (primarily AITF studies) have provided a more regional picture
    - Can be applied to small, remote, ungauged lakes
    - General finding was that GW contributions were small
    - Currently extending work to use AEW geochemical data to estimate saline formation water contributions to the Athabasca

Types of Potential Impacts

- Dewatering impacts associated with open pit mining
  - Of primary concern in the NAOS
- Changes to surface water balance and concomitant impacts to surface water bodies due to in-situ production
  - Potential exists for impacts to water quality in vicinity of injection
    - E.g., changes to the redox state of water that could potentially migrate to surface water receptors

Monitoring Efforts

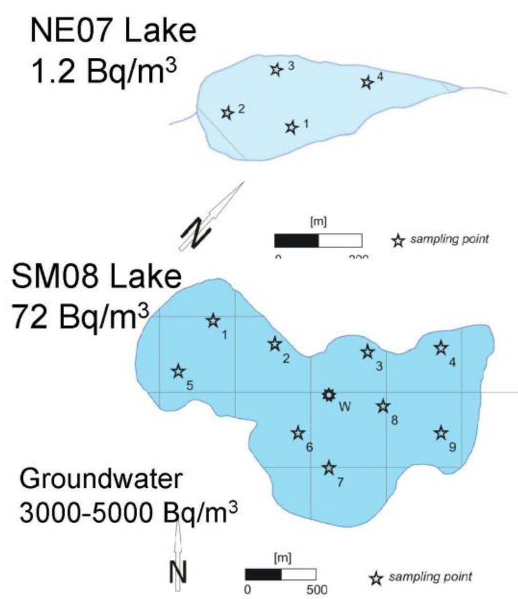
- L.A.R. Groundwater Management Framework
  - AEW
  - Does not specifically target SW-GW interaction but could be source of indices for this purpose
- L.A.R. Surface Water Quality Management Framework
  - AEW
- RAMP
  - Monitors water quality indices at 50 lakes
- Long-term River Network (LTRN)
  - AEW; focuses on Athabasca River
- Environment Canada and Gov. of Alberta
  - Main stem of Athabasca and tributaries between Fort Mac and Wood Buffalo National Park

Tools and Techniques

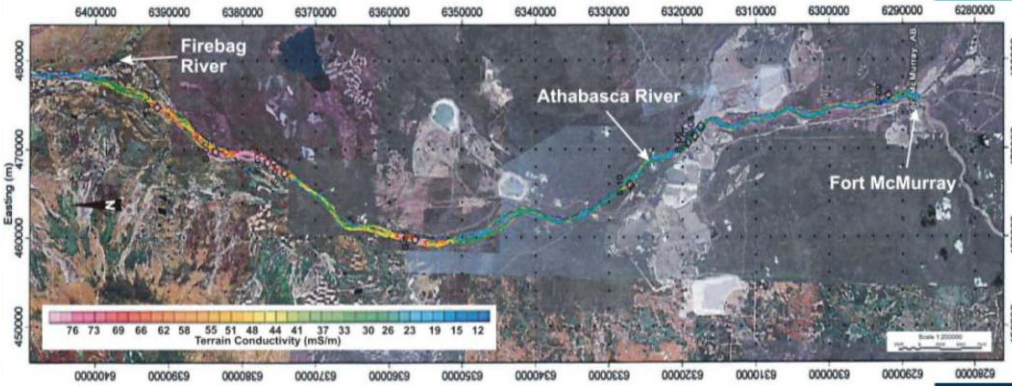
- Field Indicators (represents potential for TEK input)
- Seepage Measurement
- Hydrogeological Mapping
- Geophysics/Remote Sensing
- Hydrographic Analysis
- Darcian Flow
- Hydrochemistry and Tracers
- Thermal
- Water Budgets
- Numerical Modelling

Groundwater – Surface Water Interactions

- The site specific estimates of hydrology (evaporation/inflow) can be combined with geochemical tracers to determine the relative importance of groundwater inflows:
  - Major and minor ions
  - Radon-222
  - Age dating: Tritium, Carbon-14



Electromagnetic Survey of Athabasca River



- Two major field campaigns:
  - June 2009 (125 km) EM terrain conductivity survey.
  - Sept. 2010 high resolution secondary survey.
- 339,000 EM31 terrain conductivity measurements were collected.

Groundwater - Surface Water Monitoring

- A combination of traditional field-based hydrological and hydrogeological techniques with geochemical and isotopic tracers are well-suited to providing the kinds of regional hydrological information required for water management in the AOSR including:
  - Regional assessments of hydrology in remote, ungauged basins,
  - Regional information on groundwater surface - water interactions,
  - Sources and fate of solutes (e.g. natural and anthropogenic organic and inorganic species).

Modelling

- State of current regional GW models
- Potential for characterizing SW-GW interaction currently
  - FEFLOW – MIKE 11
  - MODFLOW ported into GS-FLOW
- The need for an assessment on what modelling tools are available
- Verbal notes on current state of SW-GW Interaction Modelling Tools

Work Plan Overview

- 2 Main Objectives
  - 1. Improve knowledge of existing SW-GW connectivity
  - 2. Improve ability to predict SW-GW interaction
- Broken down into:
  - Short-term objectives (< 1 year)
  - Medium-term objectives (1-2 years)
  - Long-term objectives (< 5 years)

Objective 1: Short-term

- Initiate consultation phase with 1st Nations groups regarding how TEK can be incorporated into SW-GW monitoring
- Consultation with Modellers
  - Identify what information should be collected to improve and constrain their predictive work
    - Identification of active SW-GW interaction regions
    - Parameters of interest
    - Sub-region specific priorities (i.e., what are the specific questions that need to be answered)
- Assemble existing data from AEW, ABMI, RAMP, LTRN, etc. to generate regional maps of geochemical indicators of increased SW-GW connectivity

Objective 1: Short-term

- Based on data-gaps identified in previous step, develop recommendations for developing a SW-GW monitoring framework
  - Phase 1: Identify what data is already collected that would be beneficial to the framework
    - No additional expense for analyses or sample collection needed
    - Requires coordination with AEW, ABMI, RAMP, LTRN, etc. to facilitate data sharing
    - E.g. The “secondary” and “tertiary” indicators described in the GWMF such as major ions, trace elements and isotopes could be used in calculating water balances and as indicators of increased SW-GW connectivity
  - Phase 2: Identify what additional monitoring efforts could be undertaken to provide more info on SW-GW interaction

Objective 1: Short-term

- Recommendations should address two spatial scales
  - Level 1: Coarse scale across the L.A.R.
  - Level 2: region-specific programs to address priority issues like:
    - Quantifying inputs of natural solutes and organics from formation waters (mostly NAOS but also SAOS)
    - Improving recharge estimates
    - Understanding/quantifying impacts on surface waters in the vicinity of surface mining activities (NAOS)
    - Understanding/quantifying impacts (if any) on surface water bodies (primarily SAOS)
    - Understanding potential impacts, and mechanisms for impact, of in-situ development on groundwater

Objective 1: Medium-term

- Use Level 1 data to produce database and maps of indicators that can be used as indicators of SW-GW interaction
  - Isotope mass balance models can be used to create runoff and ET maps across the LAR
  - Maps of distribution of geochemical indicators of increased groundwater fluxes
  - Maps of reaches of Athabasca and selected tributaries to show distribution of GW ages in inflowing groundwaters
  - All of the above can be used to help populate and contrain corresponding modelling efforts

Objective 1: Medium-term

- More focused TEK consultations if more local priority areas have been identified
- Initiate series of focused research programs based on specific SW-GW interests for the differing activities in the LAR
  - Assemble existing plan view and x-section resistivity (and thermal) surveys to identify areas of increased gw input to target additional sampling and instrumentation campaigns
  - Under ice synoptic surveys of selected isotopic, geochemical and organic profiling and age dating (improve understanding of sources, ages and natural composition of waters discharging to different portions of rivers)
  - Select Athabasca reaches to target remote sensing studies (e.g., fiber optic, thermal, cross-conductivity studies)

Objective 1: Medium-term

  - Characterize salinity and organics in gw discharge to establish natural contributions to rivers
- Improve distributed recharge estimates across LAR
  - Isotope mass balance studies using O18 and H2 in lakes across region (calculate E/I, mm/yr runoff).
  - Combine with geochemical and Radon-222 to determine gw contributions to lakes
- Surface mining impacts studies
  - E.g., Identify pilot site where development proposed or in early stages
    - Perform continuous stream-bed temperature study to determine gw fluxes
    - Supplement with seepage quality monitoring to determine any changes associated with changes in fluxes

Objective 1: Medium-term

- Understanding impacts of in-situ development
  - Use existing baseline hydrology water quality and water balance data (as available) collected by SAOS operators and compare to annual assessments of site-specific hydrology (using isotope mass balance models) and distributions of runoff parameters to identify types of surface water settings that may be vulnerable to changes in groundwater contributions
  - Use predicted shallow aquifer drawdowns (numerical models) to determine if areas with predicted changes in gw levels coincide with surface water features identified to strongly rely on gw inflows. Identify inputs/impacts of heave and source water withdrawal on interaction

Objective 1: Long-term

- Use regional datasets developed in previous stages to improve conceptual models/understanding of SW-GW interaction
  - Incorporate this data into concomitant numerical modelling work to help improve info used as model input and to constrain numerical model predictions

Objective 2: Short-term

- Background
- Closing major modelling gaps
  - Improve current conceptual models used to populate numerical models (primarily overburden deposits)
  - Spatially distributed recharge
- Develop a modelling strategy
  - Take stock of models and techniques currently being used in context of SW-GW interaction; perform independent evaluation of existing models to assess their relative quality and prediction veracity.
  - Develop a list of regional and local scale issues that will need to be addressed by numerical modelling, rank in terms of priority
  - Identify major flow and solute transport processes that may need to be included to address these issues

Objective 2: Short-term

- Perform desktop survey of available SW-GW interaction models currently available, including those already in use in the LAR)
  - Identify advantages and drawbacks of each model
  - Assess ability to successfully address priority issues of concern in LAR

Objective 2: Medium-term

- Update existing regional models
  - Update existing models with new conceptual model information (and recharge info if applicable to that modelling platform)
  - Extend current generation of models capabilities in terms of predicting/quantifying SW-GW interaction or export model input data into a more suitable platform identified in the previous phase
  - Overall objective needs to be development of regional SW-GW models that can be used:
    - To address regional issues of concern in NAOS, SAOS and Cold Lake regions
    - As the basis for supplying boundary condition to models constructed at smaller scales
  - Imperative that models are developed to the point where stakeholders have an acceptable degree of confidence in their capabilities

Objective 2: Long-term

- Shift from numerical model development to operational phase (i.e., model applications)
  - Pilot study to assess ability of updated regional models to adequately supply boundary conditions to down-scaled models applied at site or local scales
  - Apply models to address other regional and local scale issues of concern

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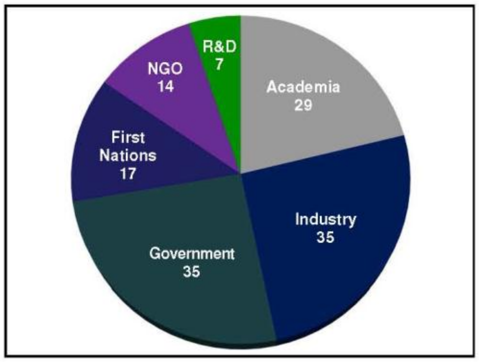
resources & energy


R&D
7
NGO
14
Academia
29
First
Nations
17
Industry
35
Government
35


96
Responses

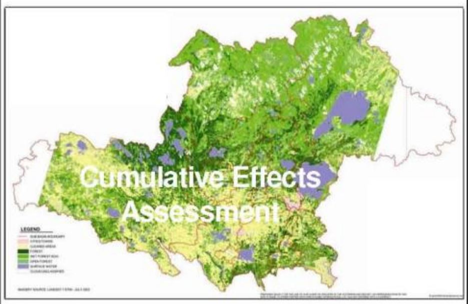

129
Initiatives

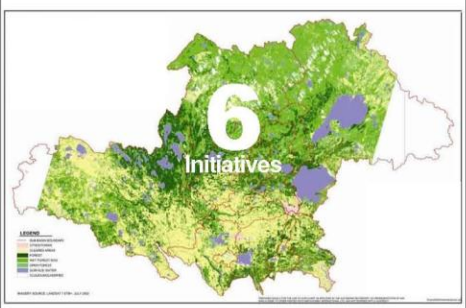
2

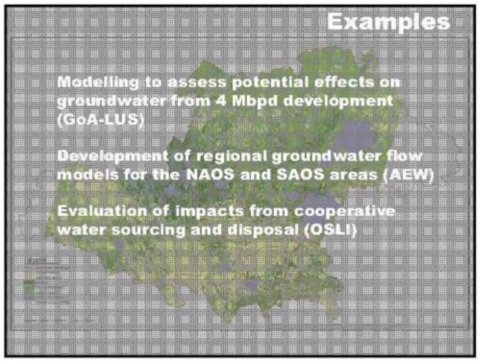
3

Examples

- Assessment of regional groundwater quality in NAOS & development monitoring network (CEMA/AEW)
- Contaminant transport study assessing loadings from natural & anthropogenic sources (AEW)
- Provincial groundwater inventory program (ERCB/AGS)
- Cap rock integrity of units above bitumen resources in northeast Alberta (ERCB-AGS)

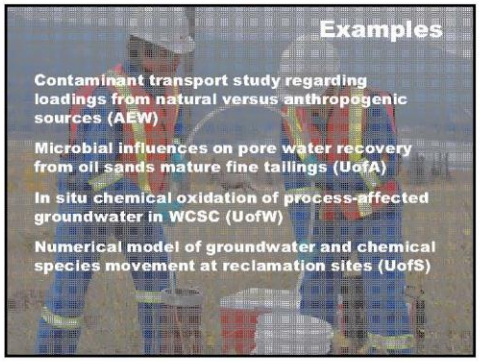





Examples
Modelling to assess potential effects on groundwater from 4 Mbpd development (GoA-LUS)
Development of regional groundwater flow models for the NAOS and SAOS areas (AEW)
Evaluation of impacts from cooperative water sourcing and disposal (OSLI)


Groundwater Quality

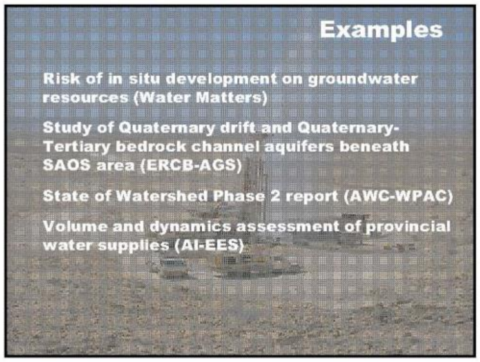

59
Initiatives

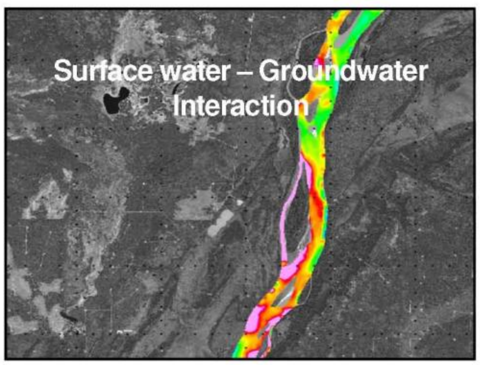

Examples
Contaminant transport study regarding loadings from natural versus anthropogenic sources (AEW)
Microbial influences on pore water recovery from oil sands mature fine tailings (UofA)
In situ chemical oxidation of process-affected groundwater in WCSC (UofW)
Numerical model of groundwater and chemical species movement at reclamation sites (UofS)

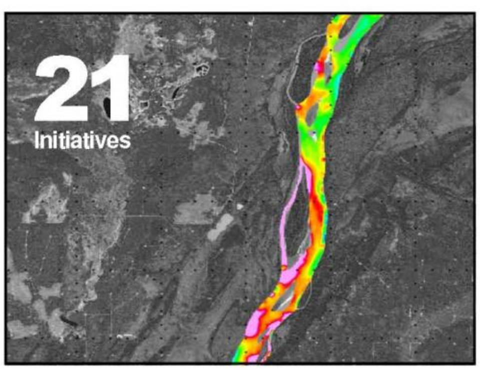

Groundwater Quantity


24
Initiatives

6


Examples
Risk of in situ development on groundwater resources (Water Matters)
Study of Quaternary drift and Quaternary-Tertiary bedrock channel aquifers beneath SAOS area (ERCB-AGS)
State of Watershed Phase 2 report (AWC-WPAC)
Volume and dynamics assessment of provincial water supplies (AI-EES)


Surface water – Groundwater Interaction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Initiatives

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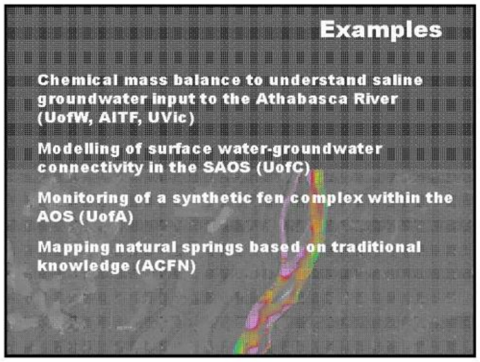
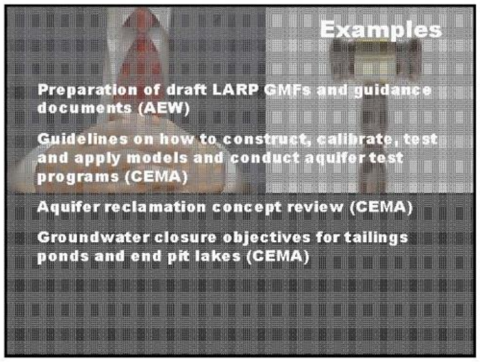
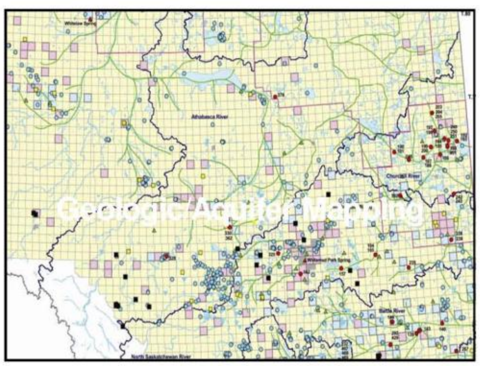
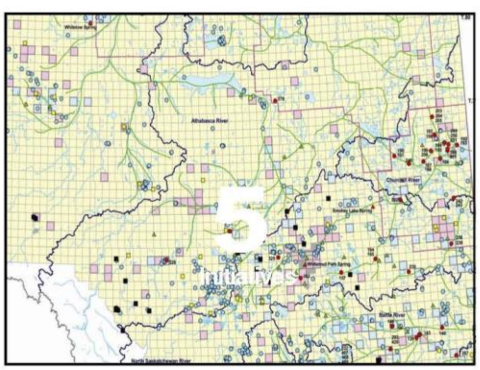

Examples
Chemical mass balance to understand saline groundwater input to the Athabasca River (UofW, AITF, UVic)
Modelling of surface water-groundwater connectivity in the SAOS (UofC)
Monitoring of a synthetic fen complex within the AOS (UofA)
Mapping natural springs based on traditional knowledge (ACFN)


Policy &
Enforcement


13 Initiatives


Examples
Preparation of draft LARP GMFs and guidance documents (AEW)
Guidelines on how to construct, calibrate, test and apply models and conduct aquifer test programs (CEMA)
Aquifer reclamation concept review (CEMA)
Groundwater closure objectives for tailings ponds and end pit lakes (CEMA)


Geologic/Aquifer Mapping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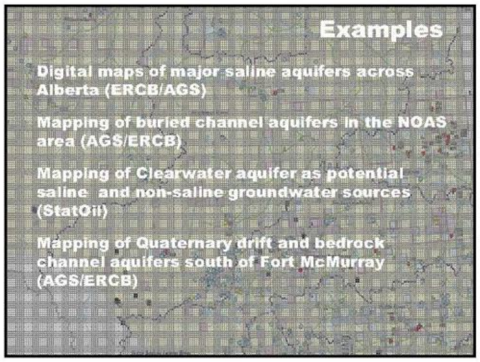
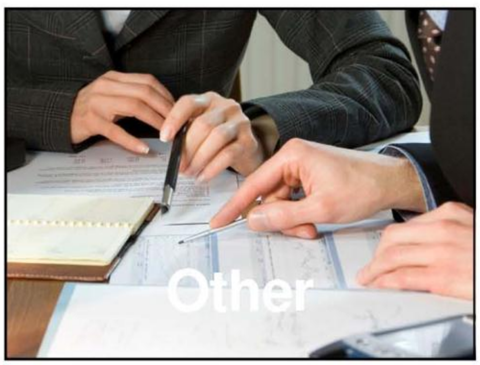
Initiatives


Examples
Digital maps of major saline aquifers across Alberta (ERCB/AGS)
Mapping of buried channel aquifers in the NOAS area (AGS/ERCB)
Mapping of Clearwater aquifer as potential saline and non-saline groundwater sources (StatOil)
Mapping of Quaternary drift and bedrock channel aquifers south of Fort McMurray (AGS/ERCB)


Other


3
Initiatives

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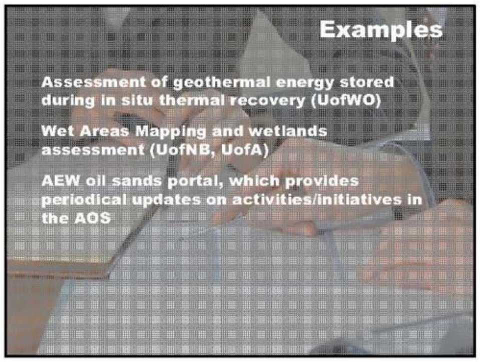
Examples
Assessment of geothermal energy stored during in situ thermal recovery (UofWO)
Wet Areas Mapping and wetlands assessment (UofNB, UofA)
AEW oil sands portal, which provides periodical updates on activities/initiatives in the AOS


Recommendations


Distribute findings to stakeholders
Develop methodology for updating initiatives
Construct interactive website for public access to review or update initiatives


Acknowledgements
CEMA groundwater working group, AEW & participating companies


WorleyParsons
Thank You
jon.fennell@worleyparsons.com
(403) 247-0200
joao.kupper@worleyparsons.com
(780) 496-9974

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APPENDIX 4: Workshop Notes

GENERAL QUESTIONS

Likelihood of Interactions and Their Impact

Question: Do you feel there are or will likely be groundwater surface water interactions as a result of mineable and in-situ oil sands operations? If so, do you expect them to be positive, negative or neutral?

In general, the participants agreed there were likely to be interactions and that they would be more pronounced in the mineable oil sands area than in the in-situ area.

Yes: Matter of the degree of communication that will be assessed by the proposed monitoring networks (NAOS, SAOS, and CLBRB). Likely little effect or a negative consequence on quality.

There will be changes to surface water – groundwater interactions due to operations. The significance of change is in questions and highly variable spatially. Uncertainty on what an acceptable level of change is.

Yes, mineable area, negative impact; in-situ less.

Mineable

> Yes likely. Unable to estimate. Qualifier but potentially negative.
>
> Short term negative interaction. Long term could be more neutral (need more information).
>
> Mine through aquifer / also SW bodies/ generally negative.
>
> Yes. Pathway identified. Contribution confirmed. Magnitude of flux unknown. Potentially negative, hard to measure.

In-situ

> Yes likely but unable to estimate qualifier but potentially negative, typically deep and more local effect. And in-situs are more flexible in its operations.
>
> Yes (ponds can leak) quality negative, quantity pressure on same qualifier negative impact.
>
> Water demand is high but most production occurs in deep GW aquifer. Heave.
>
> Less risk. Typically deeper/more removed, more localized effects. Time to react, smaller footprint.

Yes, magnitude uncertain.

Yes, magnitude and metrics uncertainty.

Yes, ambient interaction and negative neutral.

Yes, ambient relationship, neutral to negative but manageable.

Yes, there will be interactions in mining and in-situ. Will in most cases be negative except in unique circumstances.

‘Negative’? but manageable.

Don’t know enough to comment. I would assume there is potential. Thru the natural interactions we don’t fully understand.

Increase knowledge.

Monitoring to help calibrate models.

Need to understand natural interactions before we can fully understand anthropogenic impacts.

Appropriateness of Indicators

Question: Are the proposed indicators appropriate/adequate for the purposes of assessing the condition of regional groundwater quantity and quality? If not, what should be changed (i.e., added/removed)?

Quality

Indicators add calcium, magnesium, bromium, zinc.

Good, water temp.

Temperature, PAH, time series is important.

Temperature (in-situ).

Indicators identified are appropriate, however site specific. Conditions will be different then the regional indicators.

Quantity

Sustainable yield available base flow assessment, difficult one, inventory (base?) difficult to evaluate.

Base flow, wetland function (have a control and several indicators), water level, precipitation – recharge.

Water level but time series normalized. Flow direction and base flow sustainable required.

Base flow, wetland function, age dating/stable isotopes – primary. If not, what should be changed? Location?

Measurement of temporal water level measurements in aquifer (vertical gradients).

Suggestions: Hydrochemical cross sections to evaluate potential thresholds or triggers to be monitored. Consider potential surface water indicators that could be manifestations of changing groundwater flows.

Indicators as proposed are appropriate.

Would like stable isotopes to be primary indicator. Should consider outcome-based indicators. Quantity indicators are good but need to be presented so that public can understand.

Zinc/base flow separation assessment. Sustainable yield may be too difficult as indicator to define use.

Are there secondary indicators not listed in presentation?

Triggers and Limits Approach

Question: Is the use of triggers and limits to generate effective management actions a realistic approach?

Yes. However the implementation of measuring thresholds/triggers at a regional scale poses significant challenges (# of operators … who's problem).

Yes, mechanism is valid; some concerns about the immediacy of ultimate response by responsible party.

Yes, but best at local scale, under adaptive management plan. Too late at regional scale. What is going on at local scale? Reverse trends.

Yes, but will need to be on a well by well basis. Well by well vs. Regional triggers.

Quality is fine. Quantity: there are challenges with both in-situ/mining for this approach.

To an extent. Need similar risk-analysis between governments, standardized baseline, and interpretation of the data.

Baseline – well by well to get limits.

Importance of existing trends to ensure you measure real deviations.

Build into the approvals or could be a large bureaucratic problem. Ensure operator is responsible to investigate.

Improve in time: not static, revised as more knowledge gained. Revisit every 5 years.

Subject to refinement.

Step by step investigative approach is appropriate if limit exceeded.

Location of monitoring wells.

Can't just be based on triggers/limits alone. Need to look at scope of trend.

Can't set one trigger/limit value for entire aquifer, needs to be well per well.

Use of triggers needs to consider trends & greater context, not just single sampling data point.

Need site-specific indicators, triggers, limits, monitoring, and action.

Triggers/limits difficult to apply across a region. Triggers established only at well by well basis.

Trending before trigger exceeded needs to 'trigger' investigation.

Regional Groundwater Monitoring, Evaluation and Reporting Group

Question: Is there anything that should be added or changed with respect to the newly formed Regional Groundwater Monitoring, Evaluation and Reporting Group?

Structure and Function

Too early – group is still establishing Terms of Reference.

Set up Alberta Environment and Sustainable Resource Development Monitoring Panel. Panel recommends independent monitoring program, not led by government or industry (not clear who is in technical group).

Aligned with any future monitoring commission.

More information needed as the role of the RGMER and the reporting function.

More information on the role and responsibilities thru RGMER Group.

Independent monitoring – retain independent monitoring commission. Didn't follow recommendation of panel.

Backfill the science to make a world class upgrade (?).

Should have First Nation's reps.

Need to be aligned with other groups. i.e., need to be well linked to monitoring group and federal

Need a business model.

How would natural variability be captured? (baseline acquisition).

Data management – main focus/key piece. Collected, managed, assessed, standardized collection/analysis. Regional risk assessment. Minimum amount of data required in order to validate the model.

Unified data management.

Technical

Question: base of groundwater protection is measured at 4,000 mg/L. However Group has proposed to monitor up to 10,000 mg/L (non-saline monitoring?).

Groundwater quantity – NAOS – Monitoring of basal aquifer outside of many areas.

Quantity needs to be better addressed.

Needs monitoring of hydraulic head on basal aquifer, on regional scale.

Standardization of Federal/Government of Alberta data collection, management, assessment reporting/communication/modelling/risk assessment.

Regional scale risk assessment.

Regional scale Environmental Impact Assessment vs. site/project.

RESPONSES TO CHEMISTRY AND WATER QUALITY QUESTIONS

Arsenic

Question: Arsenic issues have been identified in the in-situ area. Are there any potential arsenic issues, natural and/or anthropogenic, that should be considered in mineable areas?

Thermal mobilization (yes, until proven no).

Natural arsenic in Cold Lake Area (yes, until proven no).

For in-situ the potential is real (yes, until proven no).

An issue for in-situ. Requires appropriate source and geochemical conditions. More than just arsenic (selenium, mercury, nickel, vanadium etc.).

Arsenic in mineable areas needs to be addressed – if not an issue then take it off the table.

More assessment of materials (sources: natural formations, plant tailings, overburden).

Question: Who has data on this and how can we get it? Do we need to generate new data?

AEW has it, Alberta Health and Wellness has it but it is hard to get it. Reported by operators.

Operator EPEA reports.

Yes we need new data, materials testing.

Assemble Existing Data

Question: Should we assemble existing data from AEW, ABMI, RAMP, LTRN etc. to generate regional maps of geochemical indicators of increased surface water – groundwater connectivity?

Yes. Falls back to data.

Yes. Need for a regional database as part of regional ground work characterization.

Yes. Third party agency.

Needs to be collaborative.

Shared industry/government.

Who is best placed lead? Outsourced but cost-shared between government and industry. Royalties on water to help fund or cost on disposal? Charge for disposal?

Royalty on water alienations. Waste injections.

Use Existing Baseline Hydrology Water Quality and Water Balance Data

Question: Should we use existing baseline hydrology, water quality and water balance data (as available) collected by Southern Athabasca Oil Sands (SAOS) operators and compare to annual *assessments of site-specific hydrology (using isotope mass balance models) and distributions of runoff parameters to identify types of surface water settings that may be vulnerable to changes in groundwater contributions.*

Agreed. Do an initial screening of what might be a sensitive reception.

No, not holistic enough, you would need definite tools.

You would have to combine with surface water monitoring.

Integrate to regional scale from project specific data.

Is this holistic enough? Also required.

Pathways.

Geological frameworks.

Sensitivities (aquatic habitat).

Develop List of Regional and Local Scale Issues

Question: In the context of developing a model strategy, should we develop a list of regional and local scale issues that will need to be addressed by numerical modelling, rank in terms of priority. Identify major flow and solute transport processes that need to be included to address these issues.

Yes. Ultimate goal to achieve a standardized system. Standardized verification parameters for the model. Need uncertainty analysis as part of this.

Establish objectives. Determine data needs. Select software and establish.

Develop a modeling framework predicated on:

Data needs.

Verification requirements (+/- % for steady state/water balance).

Conceptualization.

Uncertainty.

Other Priority Work

A full inventory, better inventory of the water quantity/supply in the aquifer. Need to know how much is being put back in. Both will feed the sustainable yield. Sustainable yields are important for saline.

Groundwater inventory. Recharge assessment. Life cycle value analysis on fresh vs. saline sources of water for in-situ and/or mining.

Develop a hydro geological database and conceptual hydro geological model.

Infrastructure development, backfill the science to support.

RESPONSES TO MODELING QUESTIONS

Other Models

Question: Are there models other than FEFLOW that would be more appropriate? What model scenarios would you suggest be considered for Phase 2 of the presently developed model? How do we apply the most effectively developed Model to achieve our objectives?

FEFLOW model ok when linked with surface water models.

FEFLOW is closed source, must be purchased and therefore restricts use by some people/stakeholders.

MIKESHE can be used when linked with MIKE11.

Link existing model. MIKESHE – MIKE 11. Telescope into local area.

MODFLOW is a standard universally accepted model.

However some technical challenges with open source like MODFLOW that would not provide as high quality of a product.

Model should be probabilistic and stochastic instead of predictive and deterministic (allows more honest and transparent representation for decision making).

Ideally model should be package with deformable mesh (especially for in-situ).

Need to be able to take ownership/communicate results.

Scenarios of future water use could be refined and a worst-case scenario.

Moving from Regional Scale to Project Scale

Question: How can the regional scale monitoring network/modelling be applied at the project scale?

Regional models used to indicate where localized modelling should be done. Regional monitoring gives baseline, can be used by proponents for comparison with specific sites. Regional model provides boundary conditions. Regional monitoring/modelling can identify key issues relevant to local scale.

Helps provide consistency across projects (in areas where operators are in close proximity).

No – need refined scale.

Predictive/deterministic. Probabilistic/stochastic – modelling- range of outcomes.

Can use regional boundary conditions.

Use project-scale for targeting local drilling and for baseline.

Information Required to Improve and Constrain Models

Question: Should we consult with modellers to identify which information should be collected to improve and constrain the predictive work around active surface water – groundwater interactive regions. In the group discussion consider what information you would like to see collected during this task.

Done by CEMA with Alberta Innovates – Technology Futures.

Focus on data collection rather than modeling now.

Geology – airborne geophysics – mapping. A lot of uncertainty.

Improved understanding of geology; better mapping.

Map of steaming operations overlain with surface water features.

Water levels. Condition and changes in wetlands. Isotope mass balance.

Isotopes/mass balance – calibrate model?

Desktop Survey of Models

Question: Should we perform desktop survey of available surface water – groundwater interaction models currently available, including those already in use in the Lower Athabasca Region?

Partially done in 2007 (?) – led by industry and recommend hydrogeosphere.

Low priority.

MIKESHE – McClelland Lake fen.

Identify Advantages and Drawbacks of Models

Question: Should we identify advantages and drawbacks of each model identified in task 4 and assess ability to successfully address priority issues of concern in the Lower Athabasca Region? In the group discussion consider what else we could do, other that identify the disadvantages and drawbacks of each models.

Been done in 2007 – low priority.

Inventory and Evaluate Models

Question: In the context of developing a modeling strategy should we take stock of models and techniques currently being used in context of surface water – groundwater interaction; perform independent evaluation of current models to assess their relative quality and prediction veracity.

Data gaps on regional scale create significant challenges in being able to achieve this. Therefore, data collection is key/top priority right now.

Other Priority Work

Shallow aquifer mapping (so far focus has been deep).

Surface geology mapping.

Mapping – surficial, geological.

Expansion of monitoring network – number of wells.

Expand monitoring network/met stations.

Expand isotope sampling.

Isotope/^{222}RN sampling programs.

TEK – where are the important springs?

Complete water balance.

Building common database with all players.

Determine where groundwater – surface water interaction modelling is needed. Where are the objectives of modelling?

What data is available & what is needed to achieve a groundwater – surface water interaction model?

Involves data collection. Ensure data is open.

Develop a modelling strategy:

Verification/validation of modelling is critical here.

Government led.

Funding model will be provided by cabinet.

Set standards for sampling and analysis/well construction.

This is evolving, so can't comment on who funds.

RESPONSES TO HYDROGEOLOGY AND HYDROLOGY QUESTIONS

Additional Groundwater Monitoring Sites

Question: Are there additional sites within the proposed (Southern Athabasca Oil Sands) and existing (Northern Athabasca Oil Sands, Southern Athabasca Oil Sands and Cold Lake Beaver River) groundwater monitoring network that should be added? Are there any key areas that should be addressed as priority areas?

Table feels that we are not sufficiently informed as to the existing sites that have been identified.

Likely key areas exist, however a greater understanding of the vulnerability mapping is needed.

Influence of Devonian Formation

Question: How can we better understand the influence of Devonian formation waters on groundwater and the Athabasca River?

More intensive studies on geology and hydrogeology of Devonian succession.

Greater geochemical and isotopic analysis of Devonian waters.

Continued geophysical surveys.

Salinity, metals.

All about saline water (metals).

Geophysical surveys.

Pore water sampling within streambed.

Isotope work (calibrations).

Assessment and Determination of Recharge Rates

Question: Should a thorough assessment and determination of recharge rates in the oil sands area be considered a priority?

Yes. Although discharge measurements are equally important and may help bring certainty to recharge.

Additional Monitoring Efforts

Question: Should we identify what additional monitoring efforts could be undertaken to provide more info on surface water – groundwater interaction? Surface Water – Groundwater monitoring programs can address priority issues like: Understanding/quantifying impacts on surface waters in the vicinity of surface mining activities; Understanding/quantifying impacts (if *any) on surface water bodies; Understanding potential impacts, and mechanisms for impact, of in-situ development on groundwater.*

Perhaps a best practice modelling guidelines.

AITF presentation outlines surface water - groundwater monitoring and modelling strategy quite thoroughly.

Change in groundwater chemistry.

Quality – different than quantity.

Quantity

Field date used to calibrate models.

Integrate models required for approvals, used to help with monitoring.

Coupled models (groundwater and surface water).

Focus on data management system – products second.

Put controls in place to understand processes.

Use Predicted Shallow Aquifer Drawdowns

Question: In the context of developing a better understanding of in-situ development impacts should we use predicted shallow aquifer drawdowns (numerical models) to determine if areas with predicted changes in groundwater levels coincide with surface water features identified to strongly rely on groundwater inflows. Identify inputs/impacts of heave and source water withdrawal on interaction.

Agree…generally speaking…validate with monitoring data.

Discussion focused around lack of input data and uncertainty in the range of surface heave; and modelling results in general.

Natural progression from maps.

Other Priority Work

Communication. Integration. Transparency.

Need one common data portal.

None at the present time outside of what has been discussed today.

Top 3 things we would like to see done:

Data integration and data sharing amongst agencies.

Data transfer from provincial to federal agencies.

Data dissemination.

Who leads: federal and provincial agencies.

Further discussion and brainstorming around triggers and outcomes monitoring.

Model validation.