Transitioning to an Enhanced Groundwater Management Framework in Alberta

Dan Palombi
Alberta Geological Survey
Alberta Water Demand

Sectoral Water Allocations Index

Year: 1900 to 2012

Total Allocations (billions of m³)

- Agriculture
- Commercial
- Industrial (Oil, Gas)
- Other Uses
- Municipal

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Water Use in Major River Basins

**Peace River Basin**
- Water Well Use: 46.6%
- Drilling Use: 10.4%
- Municipal Use: 9.0%
- EOR Use: 5.8%
- MSHF Use: 1.9%
- In Situ Use: 26.3%

**Athabasca River Basin**
- Oil Sand Mining Use: 85.7%
- Water Well Use: 7.7%
- In Situ Use: 5.7%
- EOR Use: 4.1%
- Drilling Use: 2.2%
- Municipal Use: 1.1%
- MSHF Use: 0.4%

**Bow River Basin**
- Irrigation Use: 85.7%
- Municipal Use: 14.0%
- Water Well Use: 7.3%
- EOR Use: 6.6%
- Drilling Use: 0.1%
- MSHF Use: 0.0%

Tony Lemay, AGS
Hydraulic Fracturing in Alberta

- Only oil and gas wells with multi-stage hydraulic fracturing since 2008 (left)
- Red dots show locations where drilling targets natural gas including deep shale formations in the Montney and Duvernay play areas
- Green dots show locations where drilling targets crude oil from conventional sandstone and carbonate formations

- Above: Sub-basin water use for multiple-stage hydraulic fracturing (2013)
Conservation: Oilfield Injection

Source Water Use Over Time
1973-2012*

*Data Source: Alberta Energy Resources Conservation Board (ERCB). Chart produced by Water Policy Branch, Alberta ESRD.
Program Objectives

Fresh and saline water focus

I. Characterize the natural system: groundwater regime, aquifer maps, reports, and data sets

II. Understand dynamics of groundwater systems: numerical models

III. Develop decision-support tools for resource management, regulation, and policy development

3 Phases of the Program

I. Characterize the natural system: groundwater regime, aquifer maps, reports, and data sets

II. Understand dynamics of groundwater systems: numerical models

III. Develop decision-support tools for resource management, regulation, and policy development

Council of Canadian Academics, 2009
Recent Advancements in Mapping Deep Regional Aquifers

1. Analytical method to examine the influence of production and injection operations on well-test analyses (e.g., Drill Stem Tests)
   - Use for mapping natural and production-affected hydraulic head distributions for regional aquifers

2. Analytical method to account for variable density flow effects using the Water Driving Force (WDF) method
   - Employ vector analysis to identify flow directions in regions where density-driven flow is important and can change the inferred magnitude and direction of flow
1. Examining the Influence of Production and Injection

- Cumulative Inference Index (CII) methodology can be implemented to identify production influences.

- The methodology assumes that production influences are analogous to water-well testing principles; meaning the effect is directly proportional to an inference index, \( \log \left( \frac{t}{r^2} \right) \).
  
  - “t” is the length of time since production and r is distance (radial proximity) between a production well and the well where pressure was measured (e.g., DST).

- The CII index for a particular DST is the cumulative sum of inference indices for pumping/injection wells in the surrounding region.

** Bruin and Hudson (1961), Tóth and Corbett (1986)
Depiction of CII Methodology

- **Search Radius (R)**
- **Drill Stem Test**
- **Production Wells (included in CII calculation)**
- **Selected DST**
- **Production well not included in CII calculation**
CII Required Data and Output

Input
- DST test location and date
- Production well locations along with production start/end dates
- Search Radius

Output
- Cumulative inference index (CII)
- Distance to the nearest well
- Number of wells within the radius (R)
- Longest production duration among the wells within the search radius
# CII Code Results

## This Code Calculates CII

Code developed by Amneepal Singh and Dan Palombi

Enter Production data file name- proddata.txt
Refer readme.txt for input/output details

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<th>Well-1long</th>
<th>DST-1lat</th>
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<th>Nearest-Well Num-wells(@spec radius)</th>
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[www.ags.gov.ab.ca](http://www.ags.gov.ab.ca)
2. Variable Density Effects: Water Driving Force Vector Fields

Water Driving Force (WDF) is a function of:

- Pressure-related driving force
- Relative density
- Aquifer structural gradient

\[ WDF = \nabla h + \frac{\Delta p}{p_o} \nabla E \]
Implementing the WDF

**Input grids of:**
- Structure top of underlying aquifer
- Hydraulic head
- Temperature
- Salinity
- Pressure

**Output**
- Water driving force (resultant and magnitude)

**Methodology**
- Water density calculated from temperature, salinity and pressure grids (Chierici, 1994, equation of state)
- Resultant WDF calculated using the equation of previous slide
- Methodology implemented in Python and ArcMap is used for visualization
Example of WDF – Python Code and Resultant Maps
Example of WDF – Resultant Maps
Assist regulator(s) of the *Water Act* using groundwater mapping and numerical models to enhance authorization process:

- Evaluate groundwater authorizations
- Support a change from well by well (Q20) evaluations to cumulative impact based assessments
- Generate regional models to assess water-balance, drawdown, and yield forecasting
- Enable scenario modelling to evaluate future groundwater developments
What Have Other Jurisdictions Done For Cumulative Effects?

Capabilities includes:

1. Reference situation
   - Historic (calibration)
   - Natural (zero extractions)
   - Recent (actual)
   - Fully licensed

2. Scenarios (impacts of change)
   - Groundwater extractions
   - Surface water extractions and discharges
   - Climate change (rainfall)

3. Output of Interest
   - Absolute values and differences in:
     - Surface water flows
     - Hydraulic heads
     - Water budgets

National Groundwater Modelling System (NGMS) in United Kingdom

[Image of NGMS in United Kingdom]
Regional Groundwater Flow Models – Taking a Nested-Scale Approach

- Local-scale groundwater management model “nested” within a regional groundwater model
- “Nested” predominantly refers to numerical boundary conditions (heads and fluxes)

More details in Paper No. 282-6
Integration of Numerical Model In Delft-FEWS (Forecasting, Evaluation & Warning System)

About Delft-FEWS:
- The software is free
- Any model can be linked to FEWS
- New displays can be added to the user interface
- Wide variety of data can be imported, displayed and used in the models
- New data can be added anytime
- Output can be automatically formatted and posted to a web server
Groundwater Model Displays in an Operational System (Delft-FEWS)

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Summary

- Continued energy resource development is relying upon available water resources overprinted on existing water use across multiple sectors.

- Characterization of deep groundwater resources is becoming increasingly important as the Government of Alberta implements its Water Conservation Policy seeking to minimize freshwater use.

- As industry moves to utilize more saline water, a more comprehensive understanding of deep groundwater will be required to manage and allocate water resources in Alberta.

- Comprehensive strategies for water resource management are being evaluated and regulatory decision-support systems underpinned by numerical models have emerged as a potential path forward.

- We are seeking a scientific linkage between regulators, model developers, policy makers, and local stakeholders in order to devise an enhanced groundwater management framework focused on understanding cumulative effects of development.
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Jon Sweetman

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