Our Understanding of Induced Seismicity in Alberta

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What is seismicity?
How is Seismicity measured?

**Modified Mercalli Intensity (MMI)**

- I
- II
- III
- IV
- V
- VI
- VII
- VIII
- IX
- X
- XI
- XII

**Effect**

- Not Felt by People
- Weak
- Light
- Moderate
- Strong. Shaking. Small objects move
- Very Strong. Felt by everyone.
- Light damage.
- Considerable damage
- Violent. Landslides.
- Few Structures Remain standing
- Total damage

**Richter Scale (local magnitude)**

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
Causes of Induced Seismicity?

- Oil and Gas Activity:
  - Disposal
  - Hydraulic Fracturing
  - Water Floods
  - Development

- Geothermal
- Mining
- Precipitation
- Water Storage Reservoirs

http://www.seismo.ethz.ch/static/100j/snapshot03/sl03_EN.html
Why Study Earthquakes

- **Surface Effects and Ground Motion**
  - Public safety
  - Property damage (buildings, roads, bridges, pipelines, water reservoirs)

- **Wellbore integrity**
  - Reservoir seal / Aquifer containment
  - Casing deformation

- **Environmental impacts**
  - Flooding
  - Tsunami
  - Landslides

- **Social License**
  - Regulatory directives
  - Stakeholder perspective
How often do seismic events occur?

https://earthquake.usgs.gov/earthquakes/search/
How often do seismic events occur?

https://earthquake.usgs.gov/earthquakes/search/
USGS 2014 Seismic Hazard Model
Including Natural Earthquakes

https://pubs.usgs.gov/of/2014/1091/v
USGS 2016 Seismic Hazard Model
Including Natural and Induced Earthquakes

Based on results from the 2014 National Seismic Hazard Model

Based on results from this study

Modified Mercalli Intensity (MMI)

https://pubs.er.usgs.gov/publication/ofr20161035
US Mitigation Measures

1. Increased monitoring and reporting
2. Traffic Light System for disposal wells
3. Seismicity review for new wells
4. Mechanical Integrity Tests
5. Public reporting

https://earthquake.usgs.gov/data/dyfi/
Earthquakes in Canada

Earthquakes in or near Canada, 1627 - 2015
NRCAN 2015 Seismic Hazard
Seismicity Mapping in the WCSB

- Canadian National Seismic Network (CNSN)
- Geoscience BC
- The Canadian Rockies and Alberta Network (CRANE)
- Regional Alberta Observatory for Earthquake Studies Network (RAVEN)
- Alberta Telemetered Seismic Network (ATSN)
- TransAlta Dam Network (TD)
- Montana Regional Seismic Network (MRSN)

http://ags.aer.ca/earthquake-monitoring
Seismicity Mapping in the WCSB

Major Bedrock Faults of Alberta

Seismic Networks:
Telemetered Stations

- ATSN (LoFC)
- CNSN (GSC)
- CRANE (IoLFA)
- MB (MB03) & US (US03)
- NERC (NCRS/CR03G)
- TD (TransAltaWU)
- RAVEN (AGS/AER)

http://ags.aer.ca/earthquake-monitoring

http://ags.aer.ca/publications/DIG_2012_0016.html
Seismicity Mapping in the WCSB


http://ags.aer.ca/earthquake-monitoring
Seismicity in WCSB

Fort St. John Cluster
Extraction and disposal (since 2000)

Crooked Lake (2015)
Hydraulic Fracturing

Snipe Lake 1970
Potentially enhanced recovery injection

Brazeau River (since 1960)
Disposal Injection

Turner Valley (1970’s)
Hydrocarbon extraction

Rocky Mountain House (1970’s)
Hydrocarbon extraction

Baranova V. et. al. 1999.
Shultz et. al. 2014; 2015
Northeast British Columbia

• **2012 Investigation of 231 seismic events:**
  – 38 induced by wastewater disposal (from 2 wells)
  – 193 induced by hydraulic fracturing events (2.6% of wells)

• **Mitigation Actions**
  – Increased seismic monitoring (new seismograph stations and dense array stations)
  – Fault mapping and identification of stressed faults
  – Data collection and evaluation of linkage between rate and pressure.
    • Important for disposal
    • Less important for hydraulic fracturing
Rocky Mountain House
Seismic events and gas production

AER OFR 2013-15
Stern et. al (2013)
Eaton Babaie (2015)
Canadian Induced Seismicity Collaboration

http://www.inducedseismicity.ca/presentations/
What are we doing?

- High density arrays
- Increased monitoring
- Disposal well licenses require seismicity review
- Traffic light approach

AER Traffic Light System – Duvernay Zone, Fox Creek

February 2015

Alberta Energy Regulator
1. Impact on Social License
   - Operator transparency builds trust in the community

2. Lack of understanding of where/why
   - Update major fault mapping
   - Mapping of geomechanical parameters
3. Understand area specific tolerance or acceptable risk
   - Hazard mapping that includes induced seismicity

4. Continued seismic monitoring
   - Before-during-after
   - Collaboration on dense array monitoring

5. Impact on Disposal
   - Most likely to face regulatory reductions

Schultz et. al. 2016
Thanks!

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