Where should I put my disposal well?: an approach to siting optimization

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Challenges and opportunities

- Unconventional oil and gas reserves in North America are considerable
- Large volumes of waste fluids are being generated that require safe disposal *(billions of gallons per day)*
- Challenges and risks exist with respect to injection
Goals

1. Identify potential disposal formations
2. Identify locations where disposal could occur at the desired volumes and time frames
3. Work towards a strategy to ensure safe and sustainable disposal by identifying:
   - economic, environmental, and social risk
   - technical and operational opportunities
Study area & information used

Atlas of WCSB for:
- disposition, thickness & depth of formations
- depositional settings and lithology
- in-situ stress conditions

AccuMap® data for:
- disposal, injection & observations well locations
- formation properties (k and Φ)
- hydrostatic pressure
- water quality
- injection volumes
- oil & gas pools
Stratigraphic section assessed

- Lower Mannville (clastics) topographic flow control
- Sub-Cretaceous unconformity some connectivity
- Wabamun (carbonates) flow SW-NE
- Winterburn (carbonates) some topographic control
- Ireton aquiclude (calcareous shale) reefs
- Woodbend (carbonates) flow S-N regional drain
- Beaverhill Lake (carbonates)
- Prairie Evaporite aquiclude (salts, collapse breccia) reefs
- Elk Point (carbonates) flow SW-NE
- Cold Lake/Ernestina/Lotsberg aquiclude (salts, carbonates)
- Cambrian (clastics) flow SW-NE
- Precambrian aquiclude (granite, meta-sediments)

Note: ◐= gas  ◆= oil  ■= bitumen
Constraints

Waste containment

Scaling potential
- Formation plugging
- Reduced well efficiency
- Plugging of pipelines
Constraints

Pressure build-up in some areas
- cumulative effects and limited disposal capacity
- trans-boundary issues

Potential impacts to existing oil/gas/bitumen reserves
- McMurray
- Wabamun/Winterburn
- Woodbend
Constraints

Induced seismicity

- Documented for other large-scale injection schemes (*e.g.*, Oklahoma)
- Subsurface structure mapping in Alberta indicates numerous features beneath study area
- Stress patterns in WCSB are conducive
- Nothing noted to date, but injection volumes have been low (*recent evidence of HF-related events in other parts of the province*)
Methodology (Injection Potential)

Multi-Attribute-Point-Scoring system (MAPS™) based on:

- geological facies
- permeability
- porosity
- production/disposal rates
- pressure head conditions
- water quality

Numerical ranking and weighting scheme employed:

\[ 1 < f(\text{attribute}) < 5 \quad \text{low potential} \quad \text{high potential} \]

Scores calculated and normalized for comparison between formations, then mapped.

Layers aggregated to provide map of “Overall Injection Potential”:

\[ \text{Aggregate score} = \sum_{i=1}^{n} A_{i(\text{rank})} \times A_{i(\text{weighting})} \]
**Methodology** (Theoretical Injection Rate)

\[ T = \frac{1.22 \cdot Q}{S_{\text{max}}} \]

Logan’s Method: based on Thiem steady state equation

Where: 
- \( S_{\text{max}} \) = maximum drawdown (m) 
- \( T \) = transmissivity (m²/d) 
- \( Q \) = flow rate (m³/d)

\[ Q = \frac{T \cdot S_{\text{max}}}{1.22} \]

Re-arrangement of equation to provide Theoretical Injection rate

Where: 
- \( S_{\text{max}} \) = maximum pressure build-up (in metres to 90% fracture pressure) 
- \( T \) = transmissivity (m²/d) 
- \( Q \) = flow rate (m³/d)
Injection potential mapping

Woodbend Group example
Injection potential mapping

Woodbend Group example
Injection potential mapping

Woodbend Group example
Injection potential mapping

Woodbend Group example
Overall injection potential

Aggregation of all data layers including:

Constraints:
- Presence of HCs/existing disposal
- Areas of hydraulic communication
- Induced seismicity risk
- Proximity to human settlements
- Proximity to jurisdictional borders

Opportunities:
- Presence of depleted oil/gas zones
- Proximity to other operations (collaboration opportunity)
- Existing access
Spatial display tool ($m^3/d$ disposal)

Disposal Potential
- High
- Moderate
- Low
- Disposal well
Most promising targets

Cambrian Sandstone

- Deep, regionally extensive interval; thick permeable sandstone
- Generally devoid of hydrocarbons
- Estimated injection rates in excess of 10,000 m³/d per well
- Very saline (>200,000 mg/L TDS)
- Scaling potential generally restricted to clays (affected by Al content of waste waters)
Most promising targets

Elk Point Group

- Deep carbonates; reef build-up in some areas
- Brecciated zones providing secondary porosity
- Estimated injection rates up to 4,000 m³/d per well
- Generally devoid of hydrocarbons
- Poor quality formation water *(salinity from dissolution of Prairie Evaporites)*
- Risk of connectivity to surface in some areas *(NE portion of study area mostly)*
Most promising targets

Woodbend Group

- Relatively deep; thick permeable carbonates
- Some hydrocarbons
- Estimated injection rates up to 3,000 m³/d per well
- Moderately saline (30,000-60,000 mg/L TDS)
- Higher scaling potential (carbonates, silica, clays, zeolites)
Some useful strategies

Avoid:

- Hydrocarbon-rich areas, except depleted oil/gas fields *(opportunity)*
- Areas too close to jurisdictional boundaries *(stand-off distances should be commensurate with pressure effects)*
- Formations lacking sufficient cap-rock & with evidence of hydraulic connectivity to other formations or surface *(geophysics and geochemistry can help identify these)*

- Assess alternatives to manage pressure build-up and reduce waste streams *(e.g. horizontal wells, ZLD)*
- Collaborate and coordinate for better management of cumulative effects
- Deploy sufficient monitoring to detect and respond
Conclusions

- A holistic approach to assessing injection potential can identify unrealized opportunities
- MCA + geospatial mapping has proven beneficial, but requires certain information
  - *in the absence of data and information, first principles can play an important role*
- Risks and opportunities need to be identified upfront and acted upon accordingly
- Monitoring is key to success of disposal strategies
- Application of the approach is very transferable
Thank you

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