A Decade of CCUS and Associated Research at the Weyburn Oilfield, Canada

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US DOE Carbon Storage R&D Project Review Meeting
Petroleum Technology Research Centre

- Non-Profit Research & Development

- Collaborative partnership with Industry, Government and Research Organizations

- Committed to reducing environmental impacts of oil production
  - STEPS (EOR Centre of Excellence)

- Research associated with CO$_2$ management
  - IEAGHG Weyburn –Midale CO$_2$ Monitoring & Storage Project
  - Aquistore
WMP has used these sites to study technical aspects of CO$_2$ geological storage.

Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic CO$_2$.

Over 20Mt of CO$_2$ injected and stored since 2000.

IEAGHG Weyburn-Midale CO$_2$ Monitoring & Storage Project (WMP) 2000 to 2012
Staged Study Areas:

Regional GeoScience Framework Area of Investigation:

>30,000 wells in study area
-11,121 drill stem tests
-6,292 wells with digital core analyses
-9,207 formation water chemistry samples
Midale Field CO2-EOR
Best Practice Manual

Introduction
- Purpose, scope, context, background, ...

Characterization
- Regional geology
- Regional hydrogeology
- Containment characterization
- Geomechanical characterization
- Geochemical characterization

Performance predictions
- CO₂ migration
- Capacity and mass partitioning
- Containment

Geochemical monitoring
- Groundwater
- Soil gas
- Reservoir fluids
- Reservoir/caprock core

Geophysical monitoring
- Geophysical char. of rock-fluid system
- Feasibility studies
- Downhole monitoring methods
- 3D seismic methods

HM and performance validation
- Prediction/measurement comparison
- Revision of Geologic Models

Well integrity
- Integrity assessment
- Design considerations
- Remediation and conversion
- Abandonment considerations
- Integrity monitoring and field testing

Risk assessment

Community outreach
Revised Model

Was improved with:

1. More detailed aquitard characterization
2. Larger area
3. More accurate subcrop mapping
4. Increased well density (800 in area)
Migration scenarios (Cavanagh, 2011)

Slightly leaky wells: 1 micron

Containment: Jurassic aquifer

Newcastle: ---
Mannville: ---
Jurassic: 1.4 Mt

Newcastle: ---
Mannville: ---
Jurassic: 20 largest pools, 1.3 Mt

• Jurassic: small pools, migrates NE
Natural Analogue Study
3D Time-Lapse Seismic: CO₂ Distribution

Monitoring regional subsurface distribution of CO₂:
• Verifying storage conformance
• A primary input for updating reservoir models
• Optimal resolving capability
• Sensitive to low CO₂ saturations
• Data repeatability is fundamental
3D Time-Lapse Seismic: Pressure vs. CO₂ Saturation

Inversion of prestack seismic data:
- Semi-quantitative CO₂ saturation and P changes
- Results are model-based
- Characterization of reservoir rock physics is essential
- Monitoring survey design is important as “long offset” data are required
Seal Integrity: Fracture Mapping

Seismic anisotropy as a proxy for vertical fracturing:

• Means of identifying potential fracture zones regionally
• Scale of individual fractures and hydraulic conductivity is not resolved
• “Fracture zones” may warrant subsequent attention
Passive Seismic Monitoring

Documentation of time, magnitude and location of seismicity:
- Public assurance
- Integrity of the sealing units
- Injection control
Soil gas monitoring: Overview

Research Providers
✓ Dave Jones et al. (BGS)
✓ Dave Risk et al. (StFX)

Measurements
✓ CO₂, O₂, N₂ conc.
✓ CH₄, C₂H₆, C₂H₄ conc.
✓ Rn, He conc.
✓ CO₂ flux
✓ C isotopes

Methods
✓ Single-depth (BGS), depth-profile (StFX) CO₂
✓ CO₂ flux (BGS)
✓ Continuous CO₂ (BGS), CO₂ flux (StFX)
✓ δ¹³CO₂, ¹⁴CO₂
Soil Gas Monitoring Data

soil gas CO₂ - October, 2011

CO₂ soil gas concentration (%)

regional grid  HP-B  HP-G  W2-25  W12-18  Kerr Property  Minard Property
Carbon Isotopes

Scatter plot of $^{13}$C on CO$_2$ with $^{14}$C on CO$_2$
- Control, Investigation (Event 1 and Event 2)
and Injection Gas samples
Well Integrity: Field Testing Program

Modified coring tool:
→ Direct confirmation of cement
Pressure transient test confirms cement effectiveness
Process: Geosphere & Biosphere Risk

**Geosphere Risk Assessment**

**Technical Inputs**
- Wellbore integrity research
- Characterisation of reservoir characteristics & transport of CO$_2$
- Seismicity of area
- Characterisation of CO$_2$ reactions in reservoir
- Monitoring techniques & effectiveness

**Outputs**
- CO$_2$ risk events (initiating event & pathway) & ranking
- Mass of CO$_2$ released if event occurs
- Likelihood of each event occurring & releasing CO$_2$

**Other Technical Inputs**
- Characterisation of aquifers
- Characterisation of surface water
- Characterisation of soils / sediments
- Behaviour of CO$_2$ in soils, sediments, groundwater, surface water
- Receptors in environment
- Toxicology (animal, plant, human)

**Outputs**
- Risks to biosphere assets (ranking & severity)

**Stakeholder Engagement**

**Stakeholder Values**

**Building Capacity to Engage**

**Acceptability of Risks**

**Mitigation Measures**
Containment Risk Profile

The storage will retain most of the CO₂ injected

Weyburn - Containment risk profile

No further work would be required to demonstrate containment acceptability.
Identifying Biosphere Assets Most At Risk From Pathways

Initiating Events - Risk to Assets

- EOR Minor faults
- EOR Through faults
- Nat Seismicity-fault reactivation
- Nat Seismicity-new fracs
- Nat Seismicity-wells
- EOR Induced chem-fracs
- EOR Induced P/T-fault reactivation
- EOR Induced P/T-new fracs
- Wells Micros fracs, annuli
- Wells Casing corrosion
- Wells cement

Risk Level

- Illness, injury, fatality
- Tourism
- Oil and gas
- Agriculture
- First Nation heritage
- Heritage
- Amenity - sensory, perception
- Amenity - recreation
- Species
- Habitat, communities, assemblages
- Ecosystem function
- Property/infrastructure

Target Risk Level
Thanks for your attention