Carbon capture and storage (CCS) has been identified by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) as a technology that will play a crucial role in reducing CO₂ emissions to the atmosphere. In Canada, Shell, on behalf of the Athabasca Oil Sands Project venture (Shell Canada Energy, Chevron Canada Limited, Marathon Oil Canada Corporation), announced in September 2012 that it was proceeding to construct the Quest Carbon Capture and Storage project. QUEST will capture more than one million tonnes of CO₂ per year from the Scotford oil sands bitumen Upgrader located near Edmonton, Alberta, reducing the direct CO₂ emissions from the Upgrader by up to 35%. The captured CO₂ will be injected into the Basal Cambrian Sandstone, a deep saline aquifer located at a depth of about 2 km below ground surface, over a potential time period of 25 years. Quest is the first large-scale commercial application of carbon capture and storage technology at an oil sands operation. An important part of the QUEST project is its Measurement, Monitoring and Verification (MMV) plan to demonstrate containment and conformance of the injected CO₂. The aim of this presentation is to provide an overview of the QUEST project with a focus on Site Selection and characterization and Measurement Monitoring and Verification plan to address containment and conformance of the injected CO₂.

References Cited

CARBON CAPTURE AND STORAGE: THE QUEST PROJECT

AAPG
Annual Convention & Exhibition
June 2016

Luc Rock & Simon O'Brien
Large Scale Projects around the world (dedicated geological storage)
(source: Global CCS Institute, https://www.globalccsinstitute.com/projects/large-scale-ccs-projects)
Capture plant located in Fort Saskatchewan, approx 50 km N.E. of Edmonton
AGENDA

1. Quest overview
2. Site selection & characterization
3. Measurement, Monitoring and Verification (MMV) plan
4. Current Status
Joint Venture among Shell (60%); Chevron (20%); and Marathon (20%)

Quest CCS Project - **fully integrated** CCS (capture, transport, storage, monitoring)

- **One million tonnes CO₂ per year** capacity for 25 years
- **1/3 reduction** of Upgrader CO₂ emissions
  - equiv. to emissions from **250,000 cars** (per year)

Project **Approval** – Sept 2012

**Commercial** operation achieved – Sept 2015
OVERVIEW

- Well infrastructure
  - 2 appraisal wells
    - (~ 2 km MD)
  - 3 injection wells
    - (~ 2 km MD)
  - 3 deep monitoring wells
    - (~ 1.7 km MD)
  - 9 groundwater monitoring wells
    - (< 0.2 km MD)
CSM - Risks to containment

- SITE SELECTION & CHARACTERIZATION

- CSM

1yr <1 km radius
25yr <5 km radius

CO₂ plume extend

No faults -> No faults -> No faults

BGP

(nb: schematic, not to scale)
<table>
<thead>
<tr>
<th>Criterion Level</th>
<th>No.</th>
<th>Criterion</th>
<th>CO₂ Storage Property or Attribute</th>
<th>Eliminate or Unfavourable</th>
<th>Preferred or favourable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>1</td>
<td>Reservoir Seal Pairs, extensive and competent barrier to vertical flow</td>
<td>Poor discontinuous, faulted and/or breached</td>
<td>Intermediate and excellent, many pairs (multi-layered system)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Pressure regime</td>
<td>Overpressure, pressure gradients greater than 14kPa/m</td>
<td>Pressure gradients less that 12 kPa/m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Monitoring potential</td>
<td>Absent</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Affecting protected groundwater quality</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Essential</td>
<td>5</td>
<td>Seismicity</td>
<td>High</td>
<td>Moderate or less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Faulting &amp; fracturing</td>
<td>Extensive</td>
<td>Limited to moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Hydrogeology</td>
<td>Short flow systems or compaction flow. Saline aquifers in communication with protected groundwater aquifers</td>
<td>Intermediate and regional scale flow</td>
<td></td>
</tr>
<tr>
<td>Desirable</td>
<td>8</td>
<td>Depth</td>
<td>&lt;750-800m</td>
<td>&gt; 800m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Located within fold belts</td>
<td>yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Adverse diagenesis</td>
<td>Significant</td>
<td>Low to moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Geothermal regime</td>
<td>Gradients &gt;35 degC/km and/or high surface temperature</td>
<td>Gradients &lt;35 degC/km and low surface temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Temperature</td>
<td>&lt;35 deg C</td>
<td>&gt;35 deg C</td>
<td></td>
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<tr>
<td></td>
<td>13</td>
<td>Pressure</td>
<td>&lt; 7.5 Mpa</td>
<td>&gt; 7.5 Mpa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Thickness</td>
<td>&lt; 20m</td>
<td>&gt; 20m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Porosity</td>
<td>&lt; 10%</td>
<td>&gt; 10%</td>
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<tr>
<td></td>
<td>16</td>
<td>Permeability</td>
<td>&lt; 20mD</td>
<td>&gt; 20mD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Caprock thickness</td>
<td>&lt; 10m</td>
<td>&gt; 10m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Well Density</td>
<td>High</td>
<td>Low to moderate</td>
<td></td>
</tr>
</tbody>
</table>

### Ranking parameters

- Capacity
- Injectivity
- Containment

Central Alberta “Extremely Suitable” for CO$_2$ sequestration

after Bachu et al. (2000)
Target reservoir – BCS: deep saline aquifer (~2km below ground)
SITE SELECTION & CHARACTERIZATION

- **Target reservoir characteristics**

IW 5-35
(Gamma Ray Log)

IW 8-19
(Gamma Ray Log)

IW 7-11
(Gamma Ray Log)

**NW**

Net Sand - 42m
Porosity - 16%

**SE**

Net Sand - 39m
Porosity - 17%

Net Sand - 38m
Porosity - 17%

**Nb:** based on Vsh cut off = 0.35 and Porosity Cut Off = 0.1
SITE SELECTION & CHARACTERIZATION

- Seals characteristics

Radway 100/08-19-059-20W4/00

<table>
<thead>
<tr>
<th>Formation thickness (m)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Lotsberg (~100% Halite)</td>
<td>84</td>
</tr>
<tr>
<td>Lower Lotsberg (~100% Halite)</td>
<td>34</td>
</tr>
<tr>
<td>Middle Cambrian Shale (MCS)</td>
<td>44</td>
</tr>
</tbody>
</table>
SITE SELECTION & CHARACTERIZATION

Regional Geological Model

Zones
- Surface
- BSRAP
- Shallow Lava Park
- Upper Manville
- Cobble II
- 2nd White Spucks
- Base Fish Scales
- Jali Fiss
- Lower Manville
- Winterburn Cp
- Winterburn
- Niska
- Woodend Cp
- Irton (Along Pillar)
- Downstream Fair Lakes/Grosmont Wd.
- Ledak Fiss
- Cooling Lake
- Flathead Lake Cp
- Flathead Lake
- Mabula
- Chochise
- Carmin
- Firebag
- Slave Point
- Elk Point Cp
- Wain Mountain
- Provine Elginate
- Dan Red Beds 1
- Winnepegosis
- Contact Rapids
- Cold Lake
- Dan Red Beds 2
- Enderby Lake
- Dan Red Beds 3
- Upper Loonberg
- Dan Red Beds 4
- Lower Loonberg
- Dan Red Beds 5
- Cambrian
- UMS
- NCS
- NMS Lower
- BCS
- PreCambrian
- PreCambrian
SITE SELECTION & CHARACTERIZATION

- Modeling
  - static – dynamic
  - geochemical,
  - geomechanical
  - etc.

Pressure Scale Sector Model

CO₂ Plume Scale Sector Model
Atmosphere
- LightSource Laser CO2 Monitoring
- Eddy Covariance Flux Monitoring

Biosphere
- CO2 Natural Tracer Monitoring
- CO2 Flux and Soil Gas Monitoring
- Remote Sensing (Brine & NDVI)

Hydrosphere
- Private Landowner Groundwater Wells (discrete chemistry and isotopes on water and gas)
- Shell Groundwater Wells: Continuous EC, pH
- Discrete Chemical and Isotopic Analysis on water and gas

Geosphere
- Time-Lapse Walkaway VSP Surveys
- Time-Lapse 3D Surface Seismic
- InSAR
- VSP Surveys

Deep Monitoring Wells
- Downhole Pressure & Temperature (DHPT) above Storage Complex (CKLK Fm)
- Downhole Microseismic Monitoring

Injection Wells
- Injection Rate Metering, RST Logging, Temperature logging
- DHPT, Wellhead PT, Distributed Temperature and Acoustic Sensing, Annulus Pressure Monitoring, Wellhead CO2 Sensor, Mechanical Well Integrity Testing, Operational Integrity Assurance

Baseline
- 2010

Injection
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050

Closure
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050
Ensure Containment:

Demonstrate ‘security’ of CO\textsubscript{2} storage

- Verify absence of environmental effects
- Detect early warning signs of unexpected loss of containment
- Trigger of additional safeguards
- Safety Critical – designed to ALARP
**Ensure Conformance:**

Indicate long-term effectiveness of CO$_2$ storage

- Validate, Calibrate and Update CO$_2$ plume and pressure predictions
- Adapt injection and monitoring to optimize performance
CURRENT STATUS

GW monitoring

DHP monitoring

MS monitoring

start of injection

sensor malfunction: recently replaced
Government of Alberta, Department of Energy (DOE)
Government of Canada, Natural Resources Canada (NRCan)
Shell staff (Calgary, Houston, EU)
3rd party contractors
Partners: Chevron Canada Ltd & Marathon Oil Canada