Quest CCS
Storage and Monitoring – The First Year

CSPG CCUS Workshop Calgary
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Quest Subsurface

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Quest Project at a glance

AOSP JV

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Quest Project
Site Selection and Storage
Quest Site Selection

Selection Criteria
- Capacity
- Injectivity
- Containment
- MMV
- Pore Space Access
- Cost

Legend:
- Project Implore July 10, 2010
- Project Notes
- Formation
- Thickening Direction
- MCS Shale
- Lower Lotsberg
- Upper Lotsberg

Area of Interest

Project Description:
Project QUEST CCSD - Area of Interest

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The Storage Complex

- Deep (~2km) saline aquifer in the BCS
- Below potable water zones, zones with hydrocarbon potential
- Multiple thick, continuous seals (>150m within the complex)
- High quality (~17% porosity) sandstone reservoir
- Excellent permeability (~1000mD)
Quest Project
Operational MMV

Measuring, Monitoring, Verification for Containment and Conformance
Operational MMV Plan

First of a kind facility for both Shell and the province of Alberta

- First of a kind – conservative approach
- Comprehensive: from atmosphere to geosphere
  - Risk-based
  - Site-specific
  - Adaptive
- Independently reviewed
- Combination of new and traditional technologies
- Baseline data collected before start-up
Operational MMV Plan

Baseline 

Atmosphere 
- LightSource Laser CO2 Monitoring 
- Eddy Covariance Flux Monitoring

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

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

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

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

Closure 

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# Operational MMV Plan: Containment KPI for 2015

<table>
<thead>
<tr>
<th>Domain</th>
<th>Technology</th>
<th>Trigger Event</th>
<th>2015</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>LightSource</td>
<td>Sustained locatable anomaly above background levels</td>
<td>Green</td>
<td>Possible impact of inclement weather on system response</td>
</tr>
<tr>
<td>Biosphere</td>
<td>Soil Gas</td>
<td>Outside established baseline range</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface CO2 Flux</td>
<td>Outside established baseline range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroosphere</td>
<td>Tracer</td>
<td>Outside established baseline range</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>WPH</td>
<td>Sustained decrease in baseline pH values</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>WEC</td>
<td>Sustained increase in baseline WEC values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geochemical Analyses</td>
<td>Outside established baseline range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geosphere</td>
<td>DHPT CKLK</td>
<td>Pressure increase 200 Kpa above background levels</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DHMS</td>
<td>Sustained clustering of events with a spatial pattern indicative of fracturing upwards</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>DTS</td>
<td>Sustained temperature anomaly outside casing</td>
<td>Yellow</td>
<td>Move to automatic data retrieval</td>
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<tr>
<td></td>
<td>VSP2D</td>
<td>ID coherent and continuous amplitude anomaly above the storage complex</td>
<td>Yellow</td>
<td>1st Monitor Q1/2016</td>
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<tr>
<td></td>
<td>SEIS3D</td>
<td>ID coherent and continuous amplitude anomaly above the storage complex</td>
<td>Yellow</td>
<td>N/A, VSP2D deployed.</td>
</tr>
<tr>
<td></td>
<td>InSAR</td>
<td>Unexpected localized surface heave</td>
<td>Yellow</td>
<td>Report in 2017, after 1 year of data</td>
</tr>
</tbody>
</table>
Atmosphere - Lightsource

- Measures average CO₂ over the beam length
- LightSource system installed and functional at all injection sites
- Release testing demonstrated detection and location of CO₂ emissions near IW pads
- Confirmed as technology for atmospheric monitoring at Quest
Hydrosphere - Groundwater Monitoring

- 2 years of baseline data from wells across the sequestration area
- Landowner wells sampled regularly
- Carbon isotopes used as natural tracers
- GW wells on injection sites continuously recording – a CO₂ leak should cause an abrupt drop in pH, distinct from natural sensor drift
- No indication of any issues – new sensors installed
Geosphere - Remote Sensing using InSAR

Ongoing InSAR work:

- Updated processing of natural reflectors
- Measurement point density increased
- Average displacement rate detection sensitivity of 0.87 mm/year
- Currently evaluating the data

Surface Deformation Model Update

- High case shows detectable deformation about one year post injection
- Factor of 10 uncertainty
**Geosphere - Microseismic**

- Microseismic array installed in DMW 8-19 recording baseline MS activity in November 2014 – re-installed in April 2015.

- One small ($M < -1.5$) locatable event was detected in July, 2016.
Geosphere - Time Lapse VSPs

Preliminary Results

Key objectives

- Measure the shape/size of CO2 plume & compare with modelled prediction
- Ensure CO2 remains in BCS
Geosphere - IW 8-19 Pulsed Neutron Log

• Pulsed Neutron log was run in May 2015 prior to injection (Black line), and a repeat was run after 6 months of CO₂ injection. (Red line)

• Initial Observations
  • Change in the pulsed neutron response over the perforated (Red rectangle).
  • No change in log response above or below the perforated interval or through the LMS member.

• Conclusions:
  • CO₂ is contained within the perforated interval and the BCS reservoir. (Red rectangle).
  • The injected CO₂ is mainly within the high permeability streaks (Green Arrows).
Quest Project
Reservoir and Well Performance
Pressure build-up in the BCS is forecast to be less than 2 MPa (deltaP) by the end of the project life.

- Injecting into 2 wells
- Injection pressures are lower than expected
Key Lessons Learned

- Regulatory/stakeholder engagement critical to build/maintain support
- Risk-based MMV design early in project, good baseline data is really important
- Modular construction approach worked really well – delivered the project on time and under budget

Learn a lot from doing:

- Quest area is tectonically very quiet
- Walk away VSPs able to image CO$_2$ in the BCS, DAS worked really well
- InSAR … to be evaluated
- BCS is an excellent reservoir for CO$_2$ injection
Acknowledgements

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Questions and Answers

Quest CCS Knowledge Sharing Reports

http://www.energy.alberta.ca/CCS/3848.asp