Risk Assessment for CO$_2$ Storage in Geological Formations

Moving from Cottage Industry to Industrial Application

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Outline

• Context
• Where have we been
  – In Salah
• What are we doing now?
  – DF1 - 6
• Where do we go from here?
Context

- BP has one CCS project operational (In Salah) and six others under development (DF1 – 3 publicly announced).
- Need to streamline subsurface processes to focus on what needs to be done rather than what would be nice to have.
Where Have We Been?

Risk Assessment for In Salah

- Primary focus on:
  - Capacity
  - Impact on hydrocarbon operation
  - Injectivity

- Secondary focus on:
  - Seal capacity (thick regional seal)
  - Faulting (no faulting observed above reservoir)
  - Well integrity
In Salah Gas Development
Forecast CO₂ Storage Capacity and Times (Years)

- **Block A**: 25%
- **Block B**: 20%
- **Block C**: 26%
- **Block D**: 9%
- **Block E**: 7%
- **Block F**: 13%

**Frequency Chart**

- Mean = 13.85
- 10,000 Trials
- 20 Outliers

**Forecast: Segment A**

- 10,000 Trials
- Frequency Chart
- Mean = 13.85
- 20 Outliers

**Forecast: Segment C**

- 10,000 Trials
- Frequency Chart
- Mean = 12.62
- 10 Outliers
Change in gas saturations over time, resulting from CO2 injection at three locations.
What Are We Doing Now?

Structured process for Risk Assessment:
Australia-NZ Standard for Risk Assessment

- Identification of key risks and event scenarios
- Quantification of risks
- Evaluation of risks (with stakeholder input)
- Process modification to eliminate excess risk
- Monitoring and intervention strategy to manage remaining risk
The Gaps

• Issue is not the workflow but rather the criteria that are used for evaluation
  – E.g. capacity
    – Bulk pore space vs Effective pore space vs seal capacity vs economic capacity ?
  – Bust between capacity and rate
    – Utilisation of lower perm formations challenging
• Risk Assessment
  – Tools and processes for Quantitative Risk Assessment are not sufficiently robust for use in Regulatory processes
    • Look for unacceptable consequences as primary screening criterion in under-performing projects
An Approach to Assessing CCS Projects

• Design to minimise risk
  − Site selection criteria

• Assess risks
  − Develop risk register
  − Model to understand controls on storage and potential downsides of injection rather than attempt to quantitatively predict performance over hundreds of years
  − Test – can we live with consequences?

• Monitor to manage risks
  − Look for early indicators of problems
    − e.g. pressure-mass balance inconsistencies
    − Wellbore integrity
Regional setting: WA sedimentary basins
Structural Framework: Vlaming sub-basin

- Fault-bounded basin
- Shallow water (200m)
- Close proximity to Kwinana refinery
  - 20km offshore
- Thick sedimentary succession
  - >15km sediment
- Identified as a potential storage site by CO2CRC study
Database

- Open file subsurface database available
  - variable quality / density

- 2D seismic grid
  - 9100 line km
  - variable vintage/quality

- 18 exploration wells (1967-1998)
  - variable log suite / quality
  - no discoveries
  - 2 reported oil shows
  - trace gas through drilled section
### Stratigraphy

#### 3 potential storage systems (reservoir/seal pair) being assessed:

- **Gage Sandstone / South Perth Shale**
- **Parmelia Group sandstones / shales**
- **Yarragadee Fm (sst) / Otorowiri Fm (shale)**
NW-SE cross-section across Vlaming sub-basin
Evaluating Seal Integrity
# Creating Risk Register

<table>
<thead>
<tr>
<th>Risk</th>
<th>Monitoring Data Needed</th>
<th>Mitigation</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Surface facilities</td>
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| Facilities failure : flange leakage | Leak detection  
Atmospheric concentration | Protect by minimising flanges on CO2 system,  
i) Automatic gas detection system and shutdown system  
ii) Integrity inspections / portable detection | Personal exposure limits in facilities |
| Facilities failure : Vessel / pipework failure | Leak detection  
Atmospheric concentration | i) Automatic gas detection system and shutdown system  
ii) Integrity inspections / portable detection | Personal exposure limits in facilities |
| Compressor failure : seals failure | Leak detection  
Atmospheric concentration | Instrument alarms | Personal exposure limits in facilities |
| Pipeline failure : corrosion through carbonic acid formation | Line pressure  
Atmospheric concentration | Protect through:  
i) 4th stage compressor operating conditions  
ii) Dehydration with glycol (malfunction alarms on plant)  
iii) Pipeline blowdown for long shutdown period  
iv) Integrity management  
Remote concentration monitoring | Release modelling required to evaluate implications |
| Wellhead failure : wellhead rupture and uncontrolled release | Surface monitoring | i) Automatic wellhead shutdown system (low pressure trip)  
ii) Wellhead downhole check-valve | |
| Metering failure | Calibration of meters | | |
Simulated Pipeline release into North Sea:
4 million tonnes/year for 1 year