CARBON CAPTURE AND STORAGE
RISK ASSESSMENT AND MITIGATION

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Shell Exploration and Production International
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Netherlands/Germany/Norway/UK/Ireland/Iraq/Nigeria/Gabon/Malaysia/Philippines
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DEVELOPING CCS PROJECTS – GLOBAL PORTFOLIO PLAY

Shell involvement in CCS Projects;
- Industrial scale projects in operation
- Industrial scale projects in construction
- Industrial scale projects planned
- Demonstration projects, joint industry partnerships

- Quest
- Midale
- Weyburn
- TCM
- Aberthaw
- Boundary Dam
- Peterhead
- Otway
- Gorgon
- Others
  - Barendrecht
  - Draugen
  - Dubai
  - Zerogen
  - Monash
  - Longannet
My team’s businesscard

CCS & SOUR GAS CENTRE OF EXPERTISE

Our Centre/Team liaises with experts to cover the following key areas:

1. HSE in Design and Operations
2. Subsurface Characterisation
3. Sour Gas Wells
4. Infield Flow Lines, Manifolds, Trunk Lines
5. Gas Processing
6. Acid Gas Injection and Storage
7. Sulphur Recovery, Transport and Pelletisation
8. Sulphur Marketing
9. CO₂ Capture
10. CO₂ Injection and Storage

For more information visit the CCS & Sour Gas collaborative portal: https://a100.Sharing.Shell.Com/sites/ams000159/sg/default.aspx
**WHAT DO WE DO? WHAT CAN I FIND? WHO CAN HELP ME?**

<table>
<thead>
<tr>
<th><strong>Reactive Transport Modelling</strong></th>
<th>Predictive modeling of time-dependent coupled (chemical and physical) rock-fluid and fluid-fluid interactions during transport and their impact on flow, reservoir properties, cap-rock and fault planes for $\text{H}_2\text{S}/\text{CO}_2$ injection.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline, Monitoring &amp; Verification</strong></td>
<td>Verification of leak scenarios through baseline surveys and a robust monitoring and verification framework.</td>
</tr>
<tr>
<td><strong>Containment Risk Assessment</strong></td>
<td>Shell’s $\text{H}_2\text{S}/\text{CO}_2$ sequestration strategy is to search widely for sub-surface “container” options, utilising a well-defined risk assessment framework for such investigations.</td>
</tr>
<tr>
<td><strong>HSE in Design and Operations</strong></td>
<td>Sour gas operations demand compliance with the highest HSE standards. Specific HEMP (Hazards &amp; Effects Management) tools must be applied to mitigate toxic risks associated with $\text{H}_2\text{S}$ and $\text{CO}_2$.</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>Current technology developments for CCS and Sour Gas are targeted to address the increased scale of operations; safety, reliability, availability, maintainability, cost reduction and sustainable solutions for “disposal” of the $\text{H}_2\text{S}/\text{CO}_2$ stream.</td>
</tr>
</tbody>
</table>

**CCS & Sour Gas Knowledge Base**

The CCS & Sour Gas Knowledge Base is a useful starting point for exploring the vast amount of knowledge and experience. Connect to our Standards, Guidelines, Practices Worth Replicating (PWRs) and Lessons Learned.

**CCS & Sour Gas Discussion Forums**

The CCS & Sour Gas Discussion Forums provide access to Q&A’s on technical and business aspects around Contaminated Gas and is accessed through SIGN, a web-based forum tool.

For further details contact Max Prins (PTU/DC, Rijswijk), Manager of CCS & Sour Gas Centre of Expertise. Call +31 610 972 499 or E-mail Max.Prins@shell.com
DEFINITIONS

- **Risk**
  - The probability that an event will occur.
  - It encompasses a variety of measures of the probability of a generally unfavourable outcome.
  - Risk = Function of the likelihood of occurrence and consequence

- **Uncertainty**
  - The condition in which reasonable knowledge regarding risk, benefits, or the future is not available.

- **Probability**
  - The relative possibility that an event will occur as expressed by the ratio of the number of actual occurrences to the total number of possible outcomes.
RISK ANALYSIS = Integrated, iterative process

- Identify Risks
- Implement Safeguards
- Risk Evaluation
- Project Design
- Decisions

- Economic evaluation
- Infrastructure
- MMV Program
- Storage Life
- Volumetrics
- Site Selection

- Containment
- Capacity
- Injectivity
- Conformance
- Stakeholder
- Financial
- HSSE

- Site Characterisation
- MMV
- Engineering Design
- Contracts & Procurement
- Legislation & Regulations

- Semi-Quantitative
- Quantitative
- Qualitative
- Uncertainty Analysis
CCS PROJECT OBJECTIVES

- Look at the Integrated System
  - Capture volumes
  - Integrated Engineering Design – Capture, pipeline, storage
  - Capacity
  - Injectivity
  - Well count
  - Cost

- Verify Storage Performance
  - Validate, calibrate, update performance predictions
  - Adapt injection & monitoring to optimise performance
  - Ensure timely transfer of long-term liability
  - CO2 inventory reporting

- Ensure Containment
  - Detect early warning signs for any loss of containment
  - Activate safeguards to reduce containment risks to ALARP
  - Demonstrate effectiveness of any control measures deployed
RISK ANALYSIS: MUST CROSS THE FULL PROJECT LIFECYCLE

- **Pre-Injection**: Site Selection Characterisation & Baseline data collection
- **Injection**: Monitor to Verify Site Performance
- **Closure**: Monitor to Inform Site Closure Process
- **Post-Closure**: Minor Project Monitoring May Be Needed

Illustration; Benson 2007 WRI Presentation
CCS SEQUESTRATION WORKFLOW

Communication and Consultation
Company, Government, Regulator, Landowners ....

Site Characterisation
- Evaluate Storage Feasibility
- Select Storage Site
- Evaluate Site-Specific Storage Risks
- Characterise Geological Safeguards
- Select Engineered Safeguards
- Evaluate these Initial Safeguards
- Storage Risks Suitable?
  - no
  - yes

MMV Plan
- Establish Monitoring Requirements
- Select Monitoring Plans
- Establish Performance Targets
- Identify Contingency Monitoring
- Identify Control Measures
- Evaluate these Additional Safeguards
- Storage Risks Acceptable?
  - no
  - yes

MMV Plan
- Evaluate Monitoring Performance
  - Monitoring Performance Acceptable?
    - yes
    - no

Adapt Monitoring Plans
- Continue

Evaluate Storage Performance
- Storage Performance Acceptable?
  - yes
  - no

Implement Control Measures
- Continue

Performance Review & Site Closure
- Site Closure
  - Continue
  - Final Yes

Communication and Consultation
Company, Government, Regulator, Landowners ....
**ALARP Risks**

**Bowtie Analysis**

- Prevention & Recovery
- Barriers – Passive & Active
- Hardware or Processes

**Risk Management**

**EASYRISK**

- Workflow
- Modelling
- Engineering

**Uncertainty Management**

**TESLA**

- Data Collection
- Analysis
- Understanding
Hierarchical Risk Reduction - Barrier Optimisation

**Eliminate**
- Eliminate the hazard

**Substitute**
- Use processes or methods with lower risk impact

**Isolate / Separate**
- Segregate hazards and/or targets

**Engineer**
- Engineered Safeguards
  - **PREVENTION** Design to prevent an unwanted event
  - **RECOVERY** Design to mitigate harmful consequences

**Organisation**
- Organisational Controls
  - Training, Competency, Communication

**Procedures**
- Procedural Controls
  - Operating procedures, Work instructions, Permits
  - Maintenance regimes
  - Emergency Response procedures

**Personal Protective Equipment**
- Protect the person
SITE CHARACTERISATION

- Site Specific
  - Risk Profile
  - Uncertainty Profile
- Capacity, Injectivity, Containment, MMV

### CO₂ Storage

<table>
<thead>
<tr>
<th>CO₂ Storage</th>
<th>Advantages</th>
<th>Issues</th>
<th>Field Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGR &amp; EOR</td>
<td>Increases HC recovery &amp; economic gain</td>
<td>Timing Recycled CO₂ injection profile</td>
<td>Weyburn Salt Creek</td>
</tr>
<tr>
<td></td>
<td>HC Seal Proven</td>
<td>Well count/integrity</td>
<td>K12B Denver unit</td>
</tr>
<tr>
<td></td>
<td>Data &amp; knowledge rich area</td>
<td>CO₂ remains mobile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Common Practise in O&amp;G industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depleted Fields</td>
<td>Production license period ended</td>
<td>Timing Well count/integrity</td>
<td>In Saleh Barendrecht</td>
</tr>
<tr>
<td></td>
<td>HC Seal Proven</td>
<td>Repressurisation pore collapse</td>
<td>Miller</td>
</tr>
<tr>
<td></td>
<td>Data &amp; knowledge rich area</td>
<td>Storage Capacity</td>
<td>LaBarge</td>
</tr>
<tr>
<td></td>
<td>Monitoring wells use legacy wells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline Aquifers</td>
<td>Timing</td>
<td>Data &amp; knowledge availability</td>
<td>Sleipner Snovt</td>
</tr>
<tr>
<td></td>
<td>Large Potential Storage Capacity</td>
<td>Sustained Injectivity</td>
<td>Frio</td>
</tr>
<tr>
<td></td>
<td>Few wells acting as potential leak paths</td>
<td>Plume development &amp; Monitoring</td>
<td>Otway</td>
</tr>
<tr>
<td></td>
<td>Enhanced Residual &amp; Dissolution trapping</td>
<td>Seal extent/integrity</td>
<td></td>
</tr>
</tbody>
</table>
### CO2 Storage Property or Attribute

<table>
<thead>
<tr>
<th>Criterion Level</th>
<th>No.</th>
<th>Criterion</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>
</tr>
<tr>
<td></td>
<td>2</td>
<td>pressure regime</td>
<td>Overpressure, pressure gradients greater than 14 kPa/m</td>
<td>Pressure gradients less than 12 kPa/m</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Monitoring potential</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Affecting protected groundwater quality</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Essential</td>
<td>5</td>
<td>Seismicity</td>
<td>High</td>
<td>Moderate or less</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Faulting &amp; fracturing</td>
<td>Extensive</td>
<td>Limited to moderate</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>
</tr>
<tr>
<td>Desirable</td>
<td>8</td>
<td>Depth</td>
<td>&lt;750-800m</td>
<td>&gt; 800m</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Located within fold belts</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Adverse diagenesis</td>
<td>Significant</td>
<td>Low to moderate</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>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Temperature</td>
<td>&lt;35 deg C</td>
<td>&gt;35 deg C</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Pressure</td>
<td>&lt; 7.5 Mpa</td>
<td>&gt; 7.5 Mpa</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Thickness</td>
<td>&lt; 20m</td>
<td>&gt; 20m</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Porosity</td>
<td>&lt; 10%</td>
<td>&gt; 10%</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Permeability</td>
<td>&lt; 20mD</td>
<td>&gt; 20mD</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Caprock thickness</td>
<td>&lt; 10m</td>
<td>&gt; 10m</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Well Density</td>
<td>High</td>
<td>Low to moderate</td>
</tr>
</tbody>
</table>

Ref: Dr S. Bachu et al
SITE SELECTION: RISK ELIMINATION/ISOLATION

- Selection criteria, scores and rational -> targets risk reduction
  - Eliminate or Isolation from key risks
- Favourable ranking of site “A” (lowering risk) choice over “B” or “C”, even at higher cost
- Better ability to engineer and control safeguards (MMV and site operations)

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Selection Rationale</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>^</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Containment</td>
<td>Thickening seals updip</td>
<td>++</td>
</tr>
<tr>
<td>Legacy wells</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Capacity</td>
<td>BCS thickening E-NE</td>
<td>-</td>
</tr>
<tr>
<td>Injectivity</td>
<td>BCS reservoir quality</td>
<td>++</td>
</tr>
<tr>
<td>MMV</td>
<td>Better access and less interference</td>
<td>++</td>
</tr>
<tr>
<td>Pore Space Access</td>
<td>Freehold –vs-crown</td>
<td>++</td>
</tr>
<tr>
<td>Cost</td>
<td>Most proximal site</td>
<td>+</td>
</tr>
<tr>
<td>Growth</td>
<td>-</td>
<td>++</td>
</tr>
</tbody>
</table>
Subsurface Risks & Uncertainties can be condensed in 5 ranked risk groups

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Risk Description</th>
<th>Key Uncertainty</th>
<th>Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wells</td>
<td>Loss of Containment Through Wells</td>
<td>Ability to drill &amp; cement gauge hole DTS (for leak detection) Integrity of Legacy Wells</td>
<td>3rd Well 3rd Well Study in Progress</td>
</tr>
<tr>
<td>Containment</td>
<td>LoC through the Subsurface</td>
<td>Structural interpretation Regional correlation of seals Geomechanics</td>
<td>HRAM, 2D, 3D, VSP 2D, logs Core, logs</td>
</tr>
<tr>
<td>Injectivity</td>
<td>Non-commercial rates of injection</td>
<td>Permeability height (Kh) Skin Non-Darcy skin, relative permeability Connected volume CO2 injectivity</td>
<td>H₂O inj. test H₂O inj. test No, SCAL (core) HRAM, 2D, 3D CO₂ inj. test</td>
</tr>
<tr>
<td>Capacity</td>
<td>Low connected pore volume</td>
<td>Compartmentalisation Reservoir properties (h, N/G, phi &amp; cr)</td>
<td>HRAM, 3D, ext.H₂O inj. test 3rd well, core</td>
</tr>
<tr>
<td>MMV</td>
<td>Conformance risk</td>
<td>Unexpected plume migration Differentiation CO₂ contamination Detectability</td>
<td>HRAM, 2D, 3D, 3rd well Water sampling ........... MDT, sampling, INSAR</td>
</tr>
</tbody>
</table>
ITERATIVE DESIGN PROCESS REDUCES RISKS

- Risk-Based
  - Identify risks
  - Address uncertainty
    - Data collection & Analysis
    - Modelling
  - Verify geological safeguards
  - Design passive engineering safeguards
  - Understand remaining uncertainty

Source: Adapted from CO2Qualstore Report (DNV, 2009)
SITE CHARACTERISATION: SYSTEMATIC EVALUATION OF PASSIVE SAFEGUARDS

- Evidence based using collective expert judgement (Univ’s; DNV)
- Informed by appraisal data and site characterization studies
- Subject to independent expert review
- May steer further studies/data gathering to reduce white space

<table>
<thead>
<tr>
<th>Threat</th>
<th>Safeguard</th>
<th>Evidence For</th>
<th>Evidence Against</th>
<th>EF</th>
<th>EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6</td>
<td>Induced stress re-activates a fault</td>
<td>B6.1 Select site with no natural seismicity</td>
<td>1. No recorded seismicity within AOR 2. Central Alberta is tectonically stable 3. No faults seen in overburden 4. Faults not critically stressed before injection</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B6.2 Select site away from known faults</td>
<td>1. No faults through seals on 2D/3D seismic</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B6.3 Select max injection pressure using geomechanics</td>
<td>1. Inject at &gt;14MPa below BCS fracture pressure 2. Fault-normal stresses remain compressive 3. Compressor &amp; pipeline rated to 14.5MPa</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B6.4 Lower Lotsberg - Reseals fault</td>
<td>1. Salt creep re-seals fault after slippage 2. Expected salt thickness is 2-36 m</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B6.5 Upper Lotsberg - Reseals fault</td>
<td>1. Salt creep re-seals fault after slippage 2. Expected salt thickness is 53-91 m</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>
- Based on collective expert judgement
- Informed by appraisal data and feasibility studies

![Risk Analysis Diagram]

- **Unacceptable**: 1 in 10^4 per year
- **Tolerable**: 1 in 10^6 per year
- **Broadly Acceptable**

**Legend**
- Passive safeguards
- Active safeguards

**Risk Metric** vs **Number of Safeguards**

**Axes**
- Risk Metric
- Number of Safeguards

**Legend**
- Passive safeguards
- Active safeguards

**Scale**
- Risk Metric
- Number of Safeguards
**MMV – RISK ANALYSIS & MITIGATION**

- **Establish Monitoring Requirements**
- **Select Monitoring Plans**
- **Establish Performance Targets**
- **Identify Contingency Monitoring**
- **Identify Control Measures**
- **Evaluate these Additional Safeguards**

---

**MMV Design**

**Identify Risks**

**Risks reduced to ALARP**

**Implement Safeguards**

**Risk Evaluation**

---

- **Risk-Based**
  - Verify geological & engineered safeguards
  - Reduce containment risk to ALARP

- **Site-Specific**
  - Tailor-made monitoring
  - Informed by appraisal data

- **Adaptive**
  - Respond to observed performance
  - Contingency plans in place
The Bow-tie Model

Control (keep within control limits)
reduce likelihood (proactive)

Prepare for emergencies
mitigate consequences and re-instate (reactive)
MANY INDEPENDENT CONTAINMENT SAFEGUARDS IN-PLACE

Legend
- **Passive** safeguards; these are always present
- **Active** safeguards, these are only present when a decision to intervene is made triggered by monitoring information

Numbers
- 34 Preventative safeguards
- 31 Corrective safeguards
A sensor capable of detecting changes with sufficient sensitivity and reliability to provide an early warning

Decision logic to interpret the sensor data and select the most appropriate form of intervention

A control response to ensure continuing containment or to control any potential loss of containment

Is it fast enough, precise enough and big enough? Can we react to the changes detected?
**Preventative Controls**

<table>
<thead>
<tr>
<th>Injection Controls</th>
<th>Corrective Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1 Re-distribute injection across existing wells</td>
<td>RM1 Repair leaking well by re-plugging with cement</td>
</tr>
<tr>
<td>IC2 Drill new vertical or horizontal injectors</td>
<td>RM2 Repair leaking injector by replacing completion</td>
</tr>
<tr>
<td>IC3 Extract reservoir fluids to reduce pressure</td>
<td>RM3 Plug and abandon leaking wells that cannot be repaired</td>
</tr>
<tr>
<td>IC4 Stop injection</td>
<td><strong>Well Interventions</strong></td>
</tr>
<tr>
<td><strong>Well Interventions</strong></td>
<td></td>
</tr>
<tr>
<td>WI1 Repair leaking well by re-plugging with cement</td>
<td>RM4 Inject fluids to increase pressure above leak</td>
</tr>
<tr>
<td>WI2 Repair leaking injector by replacing completion</td>
<td>RM5 Inject chemical sealant to block leak</td>
</tr>
<tr>
<td>WI3 Plug and abandon leaking wells that cannot be repaired</td>
<td>RM6 Contain contaminated groundwater with hydraulic barriers</td>
</tr>
</tbody>
</table>

**Exposure Controls**

<table>
<thead>
<tr>
<th>RM4</th>
<th>RM5</th>
<th>RM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inject fluids to increase pressure above leak</td>
<td>Inject chemical sealant to block leak</td>
<td>Contain contaminated groundwater with hydraulic barriers</td>
</tr>
</tbody>
</table>

**Remediation Measures**

<table>
<thead>
<tr>
<th>RM7</th>
<th>RM8</th>
<th>RM9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement of potable water supplies</td>
<td>Pump and Treat</td>
<td>Air Sparging or Vapour Extraction</td>
</tr>
<tr>
<td>RM10</td>
<td>RM11</td>
<td>RM12</td>
</tr>
<tr>
<td>Multi-phase Extraction</td>
<td>Chemical Oxidation</td>
<td>Bioremediation</td>
</tr>
<tr>
<td>RM13</td>
<td>RM14</td>
<td>RM15</td>
</tr>
<tr>
<td>Electrokinetic Remediation</td>
<td>Phytoremediation</td>
<td>Monitored Natural Attenuation</td>
</tr>
<tr>
<td>RM16</td>
<td>RM17</td>
<td></td>
</tr>
<tr>
<td>Permeable Reactive Barriers</td>
<td>Treat acidified soils with alkaline supplements</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Technology</td>
<td>Indicator</td>
</tr>
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<td>------</td>
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<td>-----------</td>
</tr>
<tr>
<td>6</td>
<td>Detect fault reactivation</td>
<td>DHPT - Down-hole pressure-temperature gauge in a WPGS observation well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DHMS - Down-hole microseismic monitoring</td>
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<td></td>
<td></td>
<td>INSAR - Interferometric Synthetic Aperture Radar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEIS3D - Time-lapse surface 3D seismic</td>
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</tbody>
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- Evidence-based using collective expert judgement
- Informed by appraisal data and site characterization studies
- Subject to independent expert review
- May steer further studies/data gathering to reduce white space
### Conceptual MMV Plan

#### Domains

**Atmosphere**
- LoSC02
- ESS
- SPH
- SSAL

**Hydrosphere (Fresh)**
- Tracers (artificial)
- Tracers (natural)
- CBL
- Waterchem
- WEC
- WPH

**Geosphere (brine)**
- INSAR
- 3D Seismic
- 3D VSPs

**Wells**
- Injector
- Monitoring well

#### Methods

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<th>Injection</th>
<th>Closure</th>
<th>Post-Closure</th>
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MMV CONTRIBUTES TO RISK ACCEPTANCE

- Based on collective expert judgement
- Informed by appraisal data and feasibility studies
PERFORMANCE & CLOSURE

Performance Review & Site Closure

The Government or Regulators View Of Remaining Risk

Closure Plan Outline

- Intro
- Project Overview
- Storage Performance Tasks for Site Closure
  - CCS Targets from the Regulator
- Storage Performance Data
  - Well inventory
  - CO2 inventory
  - Containment Performance
  - Conformance Performance
- Operating Plan Updates
  - SDP changes
  - MMV changes
- Proposed Closure Activities
  - Storage site reclamation
  - Well decommissioning
- Site Closure Certification
  - Post-closure monitoring
  - Transfer of infrastructure
- Reporting & Documentation
Risk & Uncertainty needs to be addressed at every phase of the project

Different stakeholders will focus on different risk elements

- Landowners – HSSE, Containment
- Government, Regulator – HSSE, Containment, Capacity and long term liability
- Proponent – HSSE, Containment, Capacity, Injectivity, Financial, Long Term liability

An Industrial Scale Integrated project needs to address them all

- Site Selection – Reduction/elimination/isolation from risk
- Site Characterisation – Reduction in uncertainty and remaining risk
- MMV – Risk monitoring and mitigation
- Site Closure – Risk Transfer
“Probability is not really about numbers; it is about the structure of reasoning”

– Pearl, Shafer; 1983

“Perhaps the most important aspect is not the probability number, but the evidence and reasoning it summarizes”

– North; 1995

Remember two things:
Malaysia Beach life & Bowties

– Prins; 2013