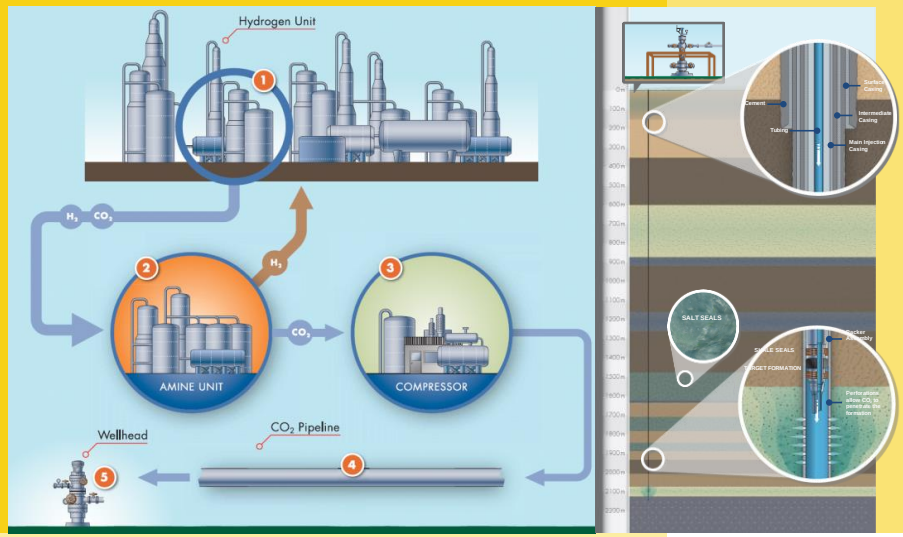
QUEST – MMV OVERVIEW

ARB Technical Discussion Series: Monitoring

Sacramento – August, 2016



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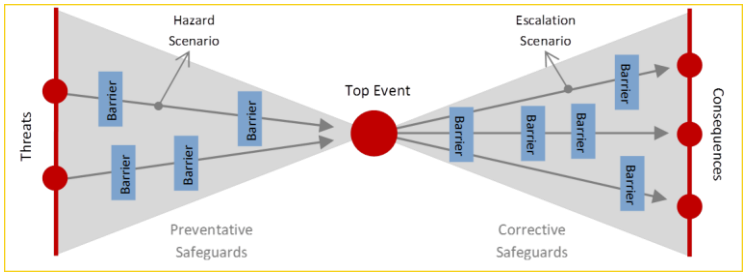
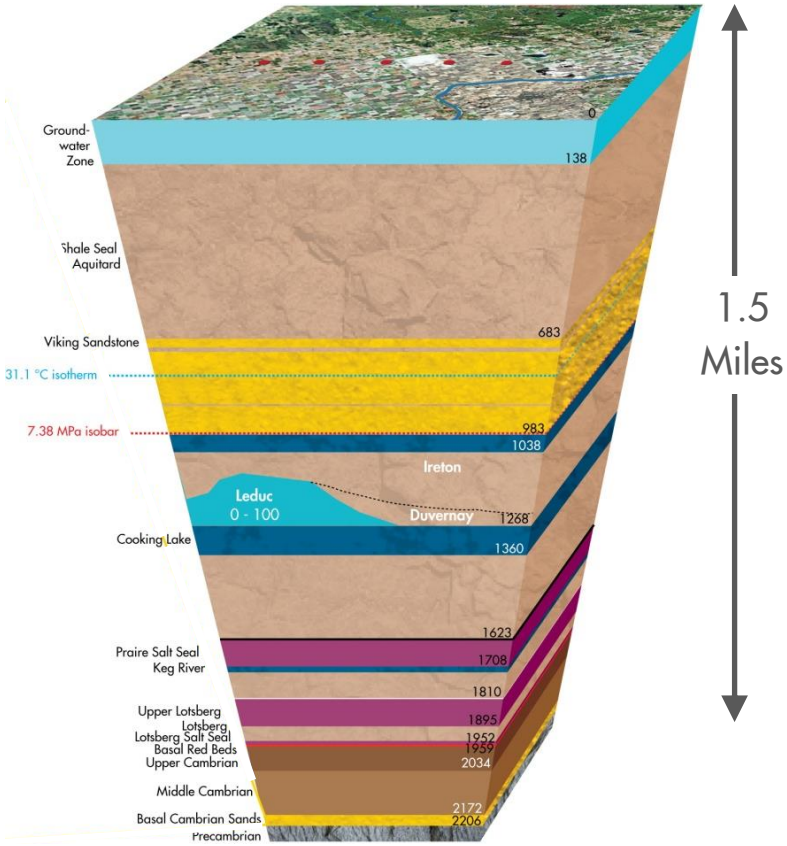
PRINCIPLES FOR CONSIDERATION

1) Presumption is zero leakage to atmosphere post-injection
   - Risk-based MMV
   - Good site selection is key
   - Revisit operational plans if migration is detected outside of primary store
   - Best engineering estimate to quantify leakage to atmosphere
   - Surface CO_2 flux can be highly variable (many factors influence) – assurance monitoring

2) Fugitives in dense phase system would be readily visible. GHGRP fugitive emission factors not appropriate for CO_2 systems.





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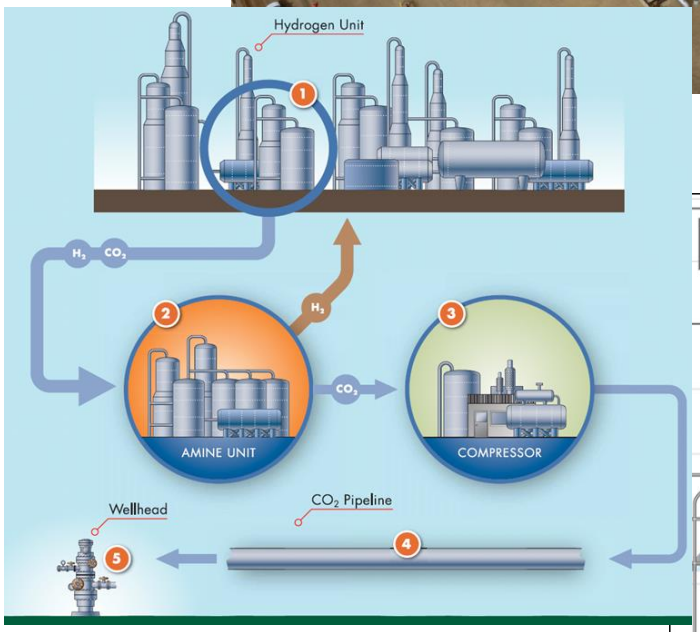
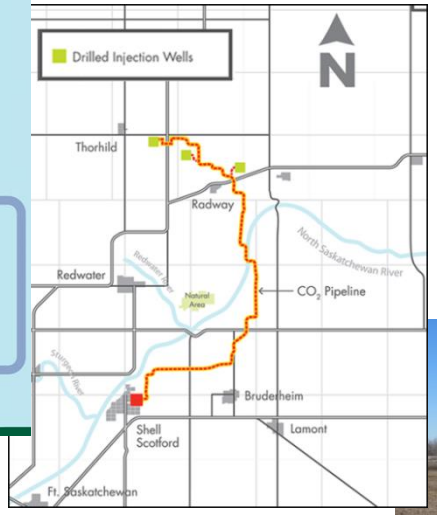
QUEST – INDUSTRIAL CAPTURE AND TRANSPORT





- Capture at the Scotford Upgrader: an Oil Sands facility that upgrades bitumen into synthetic crude
- CO_2 sources are 3 Hydrogen Manufacturing Units, captured using Shell amine technology
- Captures > 1 million tonnes per year (1/3 of the CO_2 emissions from the Upgrader) – equivalent to the emissions of about 250,000 cars
- CO_2 is dehydrated, compressed and transported in dense phase roughly 65 km to three well sites

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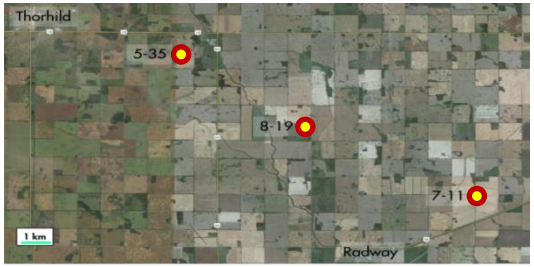
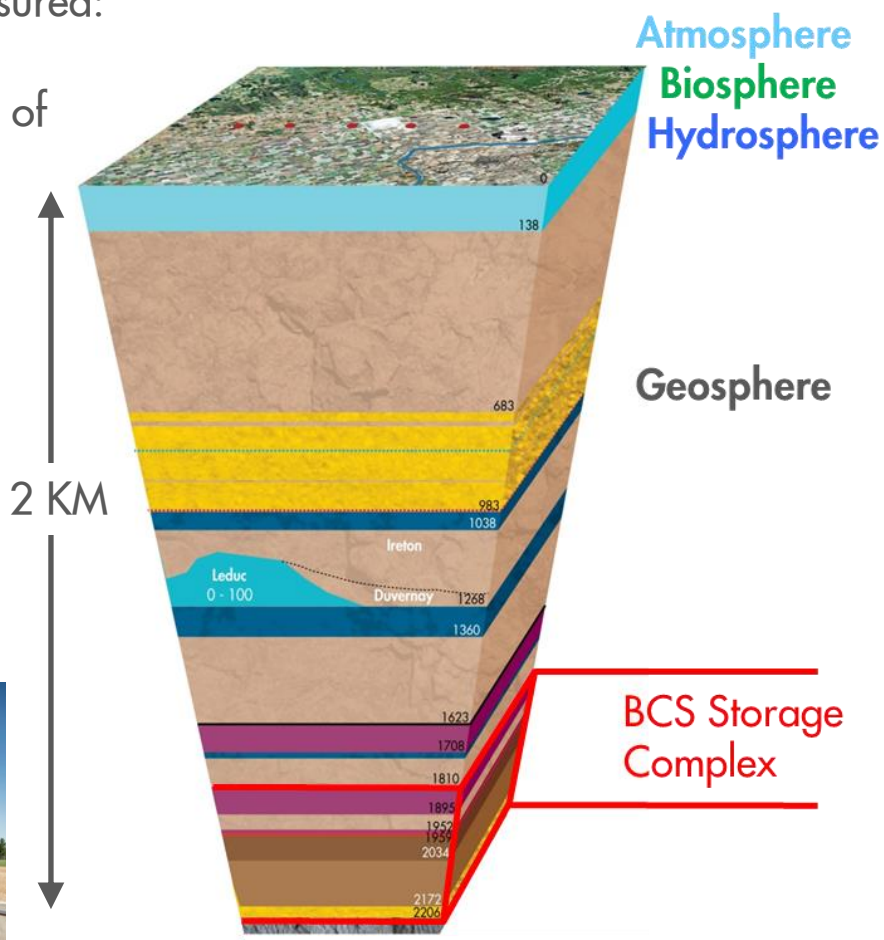
QUEST – DEEP SALINE STORAGE

- **Storage Complex**
  - Carefully selected, characterized and externally assured: complete absence of natural migration pathways
  - Reservoir: High quality sandstone (BCS) at a depth of 2000 m
  - Seals: Multiple shale and salt layers (>200m)
- **Storage Facility consists of 3 well pads:**
  - Each pad has an injection well, a deep monitoring well and multiple shallow ground water wells
  - Conventional drilling methods
  - Multiple redundant engineered barriers: 3 steel casings in injection wells through freshwater zone, all cemented to surface
- **Comprehensive MMV program**





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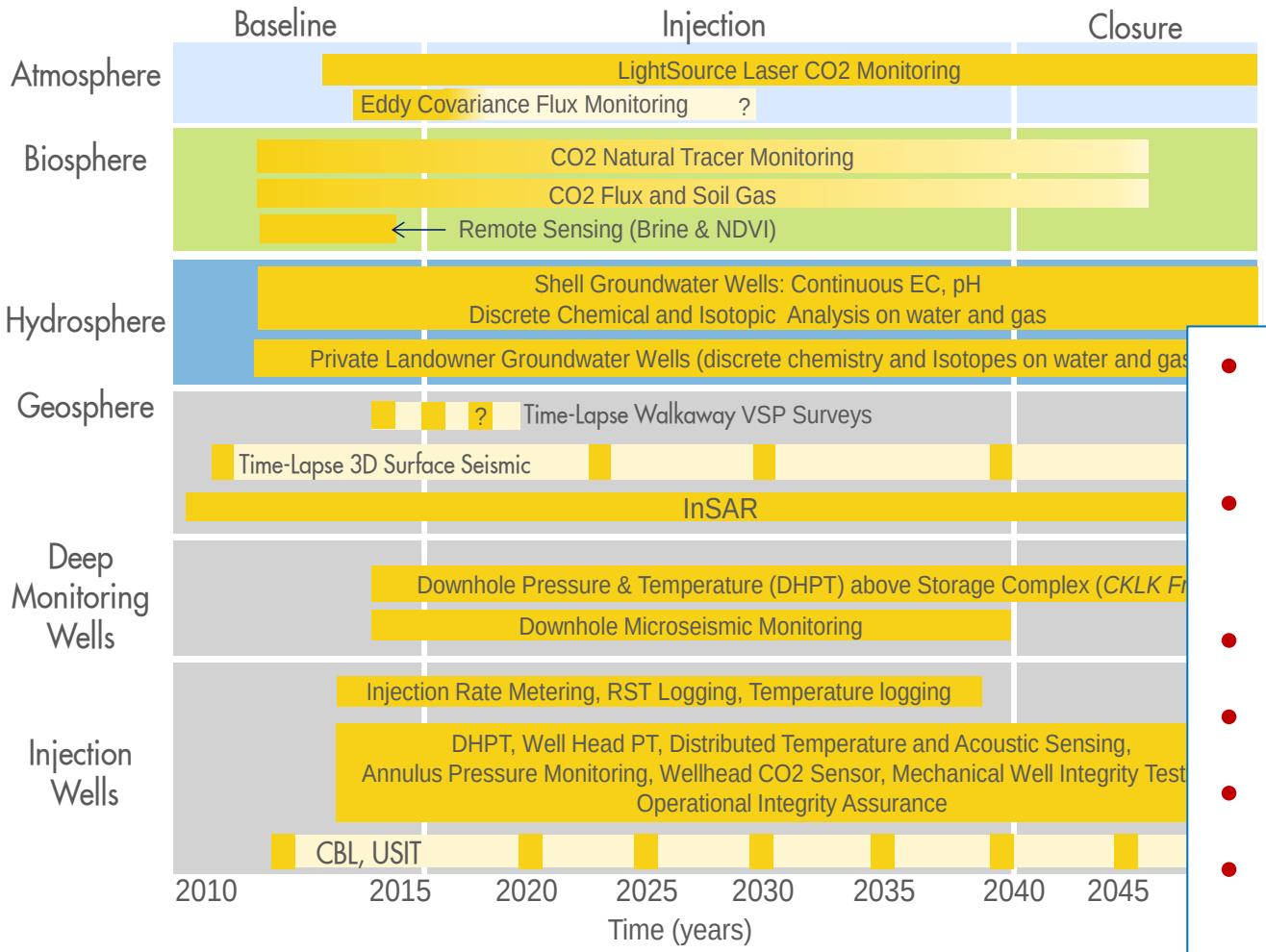
MMV (MEASURE, MONITOR AND VERIFY) PLAN



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

The original Quest MMV plan is publicly available online:

http://www.energy.alberta.ca/CCS/MeasurementMonitoringandVerificationPlan.pdf

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MMV CONSIDERATIONS

- System is designed and engineered not to leak – MMV technologies are not the primary barriers
- Three focus areas:
  - Containment (ensure CO_2 stays in zone)
  - Conformance (demonstrate we know where CO_2 is now and where it will be in the future)
  - Public/stakeholder confidence
- Timescales for action vary according to risk
  - Geologic movement very slow
  - Wells may potentially provide a faster path to the surface
  - MMV technologies must be appropriate to address the intended risk

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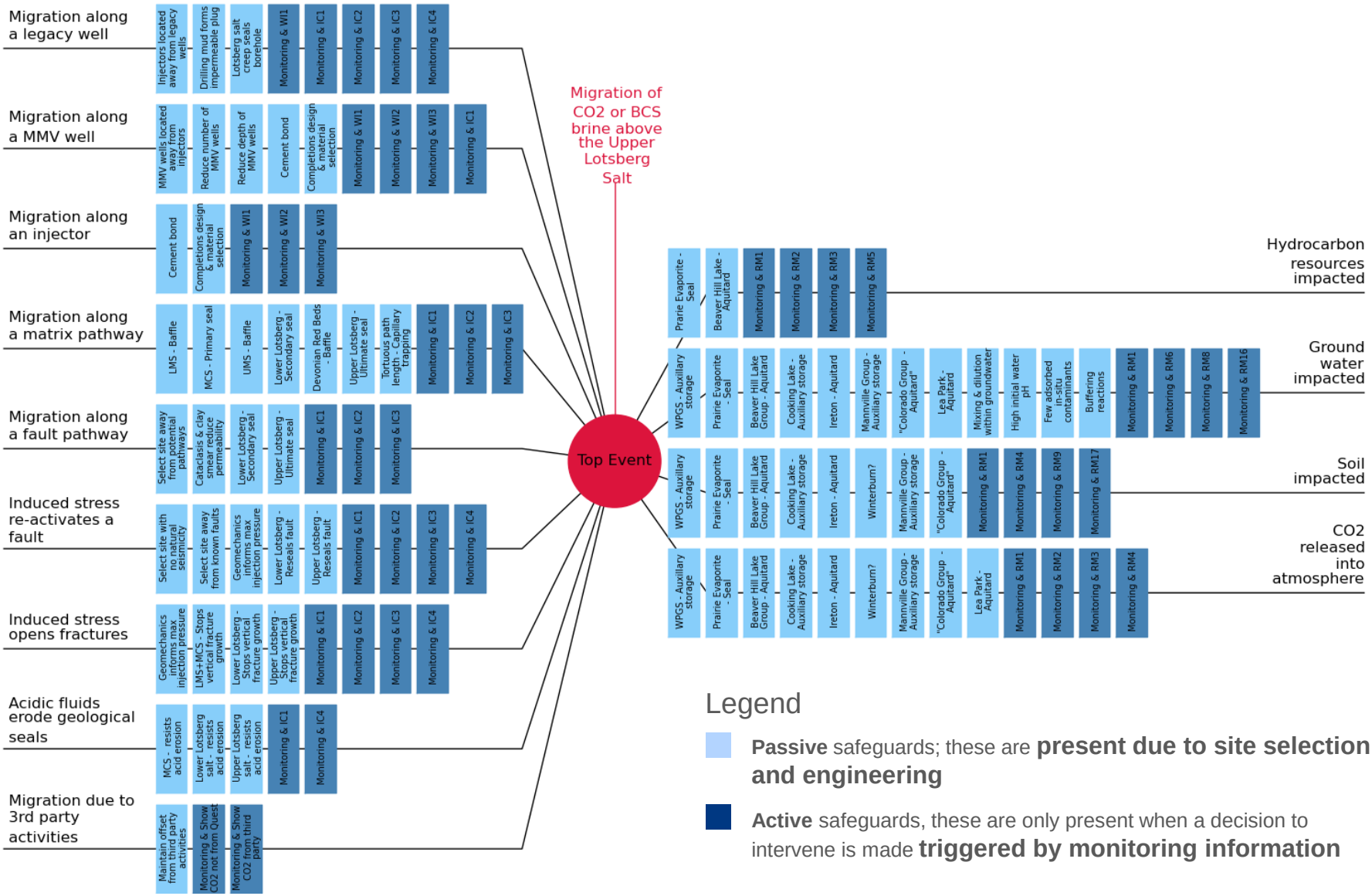
BOW-TIE: CCS STORAGE CONTAINMENT RISK EXAMPLE



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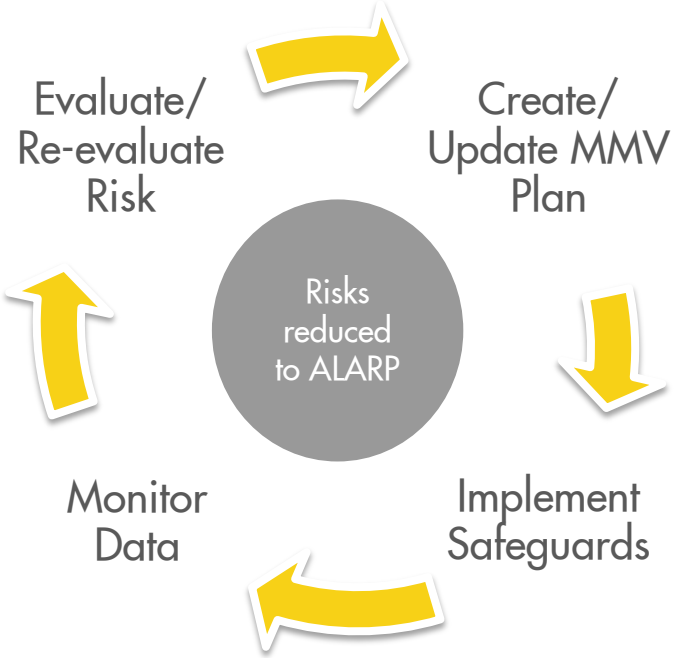
MMV DESIGN



- Risk-Based
  - Verify geological & engineered safeguards
  - Reduce containment risk to ALARP
- Site-Specific
  - Choose monitoring technologies appropriate for each location
  - Informed by appraisal data
- Adaptive
  - Respond to observed performance
  - Contingency plans in place

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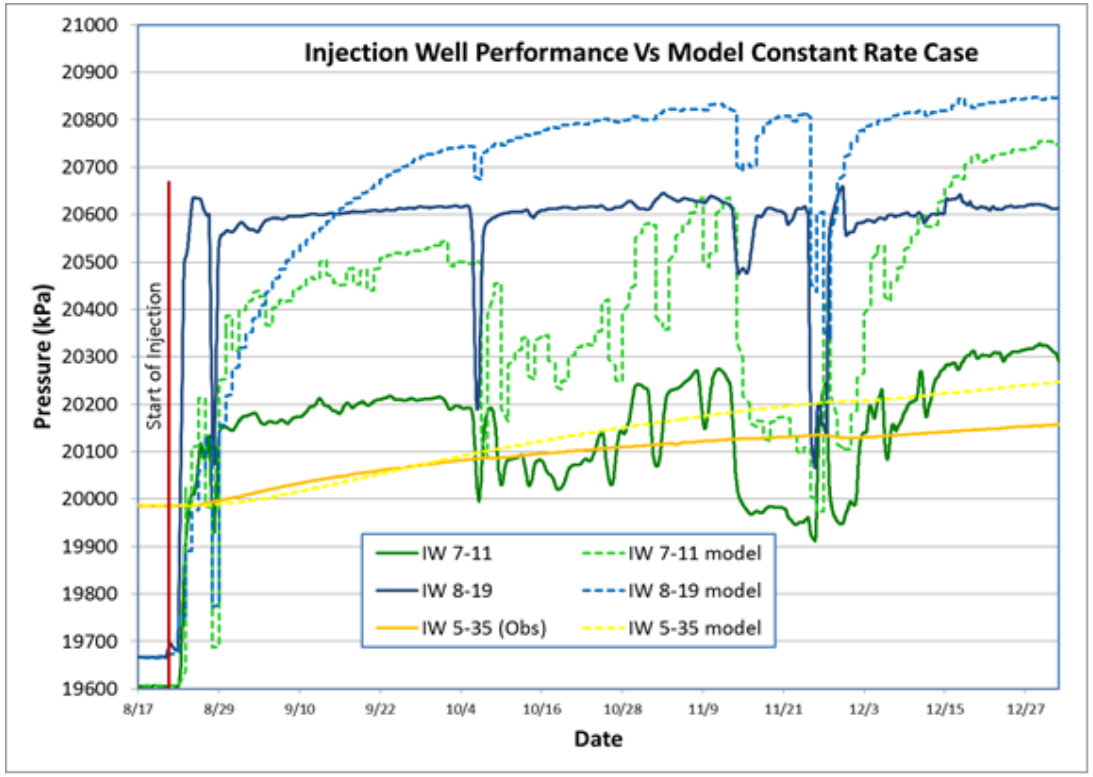
RESERVOIR PRESSURE MONITORING

- Pressure build-up in the reservoir (BCS) is less than our mid-case forecast
- Reservoir properties appear to be better than expected
- Response at 5-35 to injection at 8-19 within a day or two
- Pressure build-up in the BCS is forecast to be less than 2 MPa (ΔP) by the end of the project life

➡ Can now update our suite of reservoir model forecasts using new data



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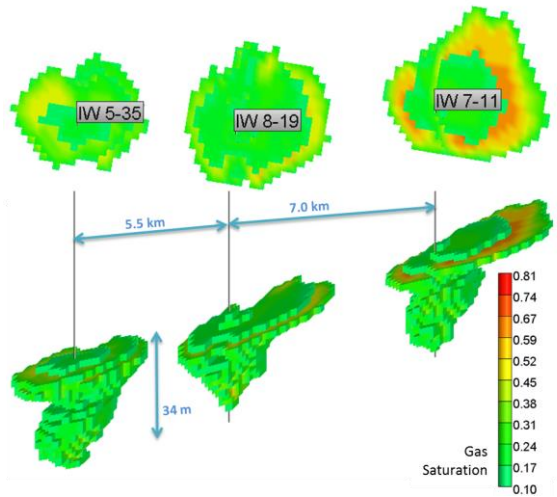
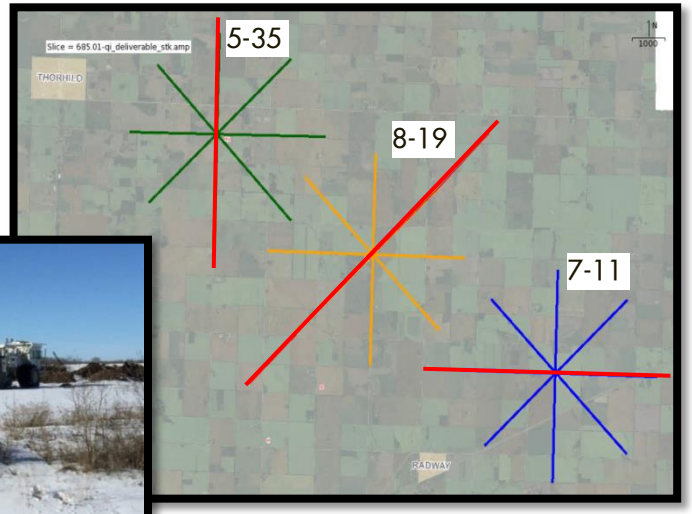
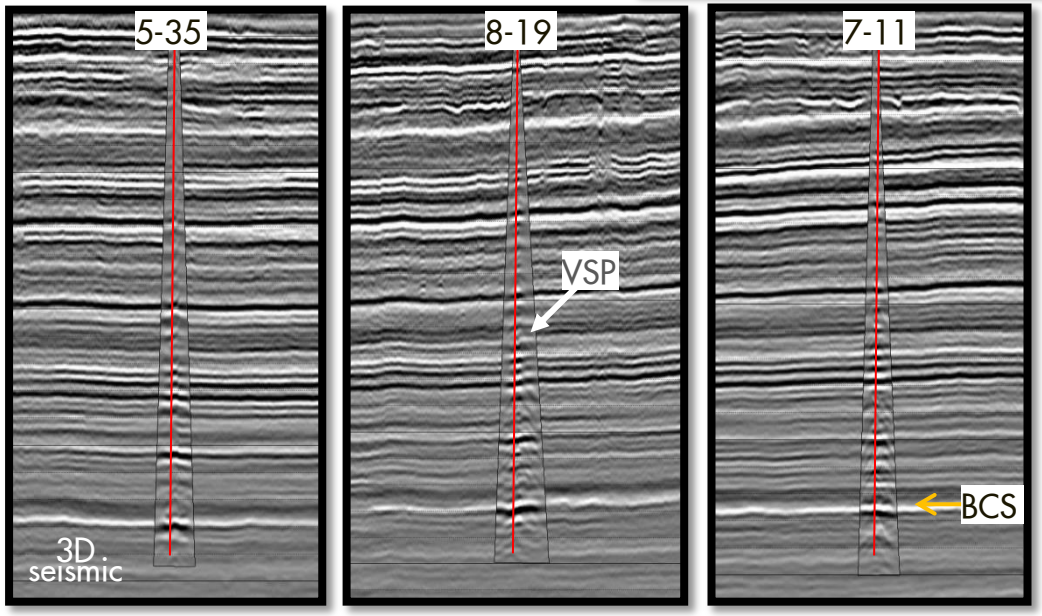
SEISMIC MONITORING – VERTICAL SEISMIC PROFILE (VSP)



Model of CO_2 Plume after injecting for 25 years





- Design change: from 3D VSP to radial walkaway 2Ds: significant cost savings
- Acquired baseline VSP in Feb, 2015 and the first monitor VSP in Feb, 2016.
- Processing is complete – still evaluating the results, but 4D response is strong

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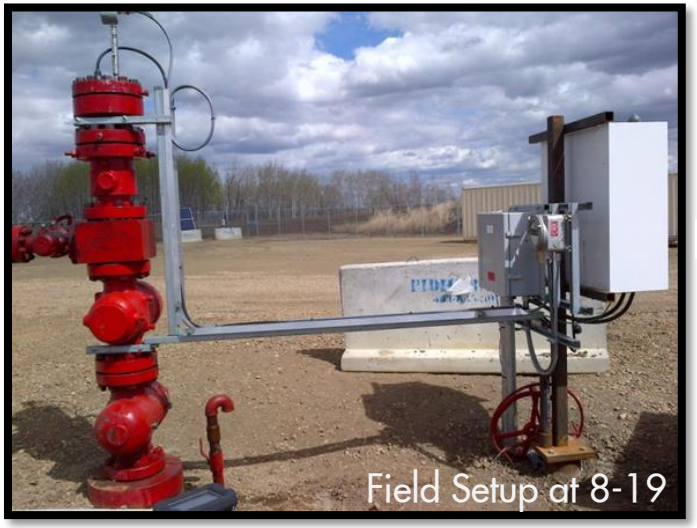
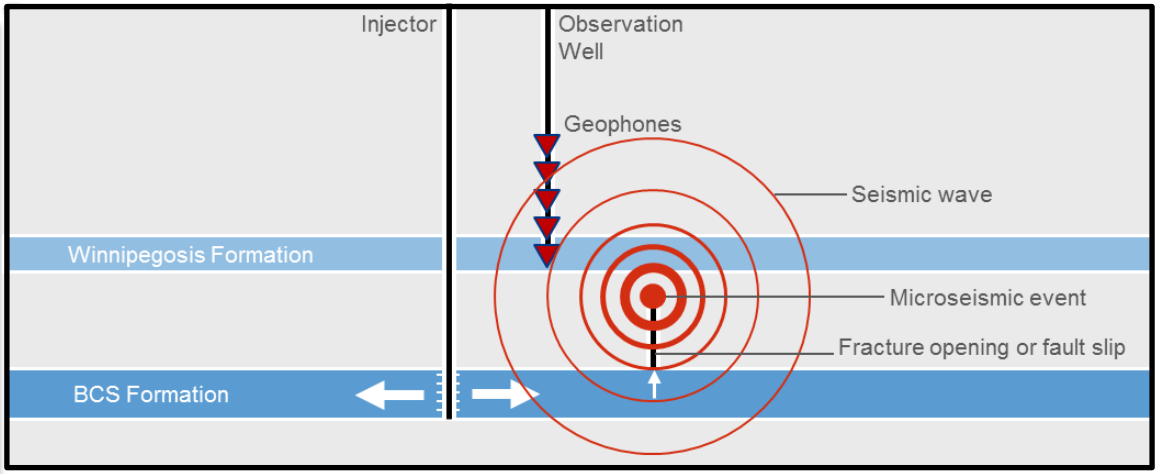
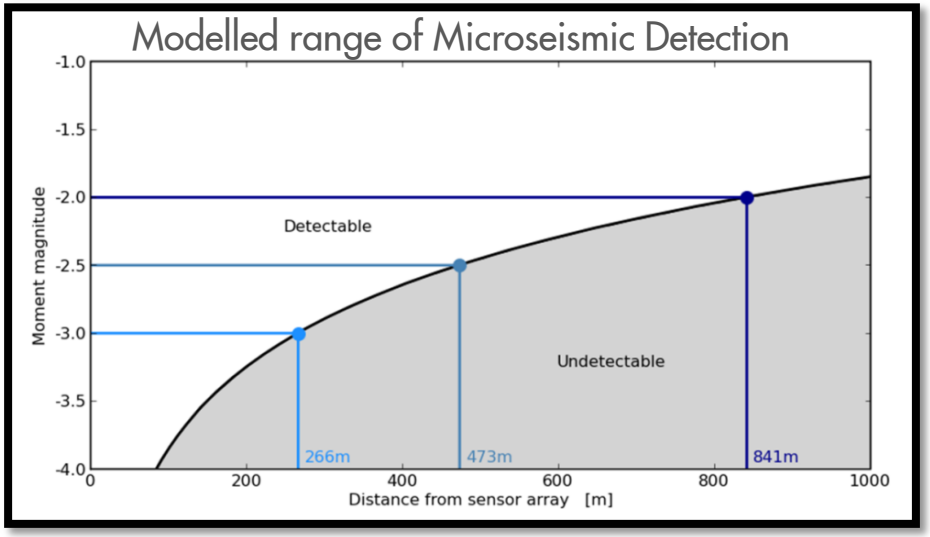
MICROSEISMIC MONITORING







- Microseismic array designed to detect events of magnitude -2.0 from a distance of ~840 m
- The array has been continuously recording since Nov 2014.
- Array is working well: numerous surface (human activity) and regional events triggered
- **No locatable events yet detected**

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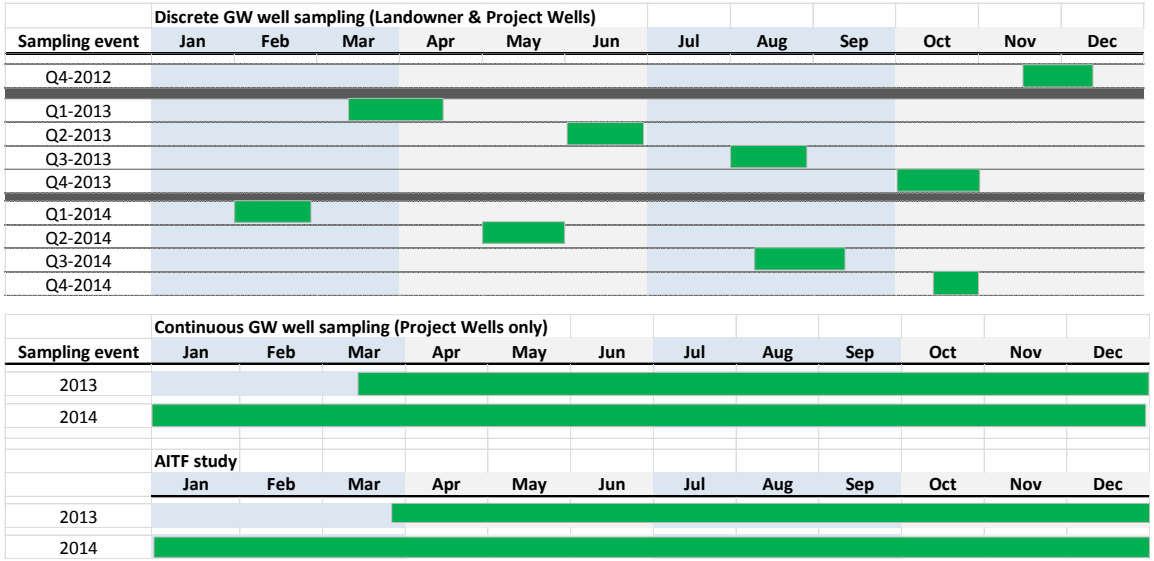
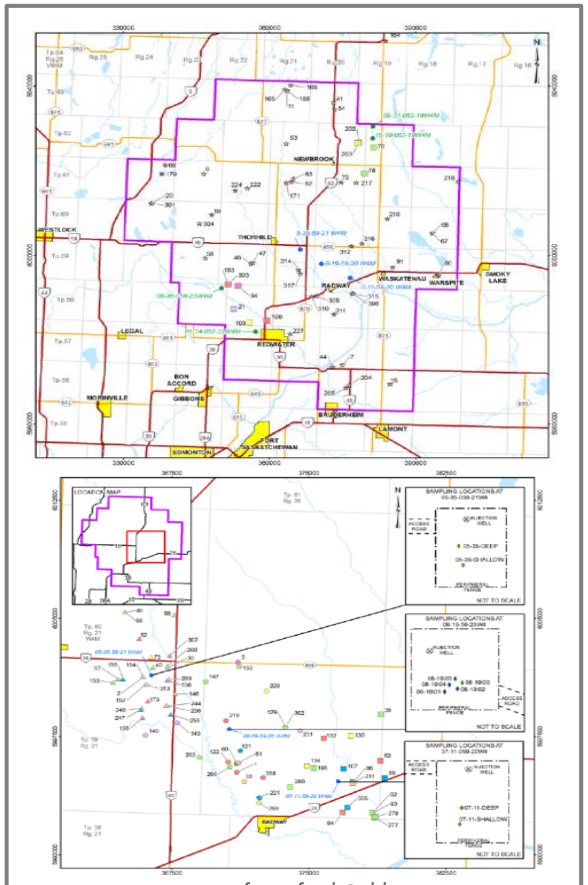
GROUNDWATER MONITORING





from final Golder report

- Continuous monitoring of Shell project wells (on well pads)
- Extensive field sampling campaign of landowner wells, many measurements taken
- Comprehensive baseline data
- Working with regulator to optimize sampling

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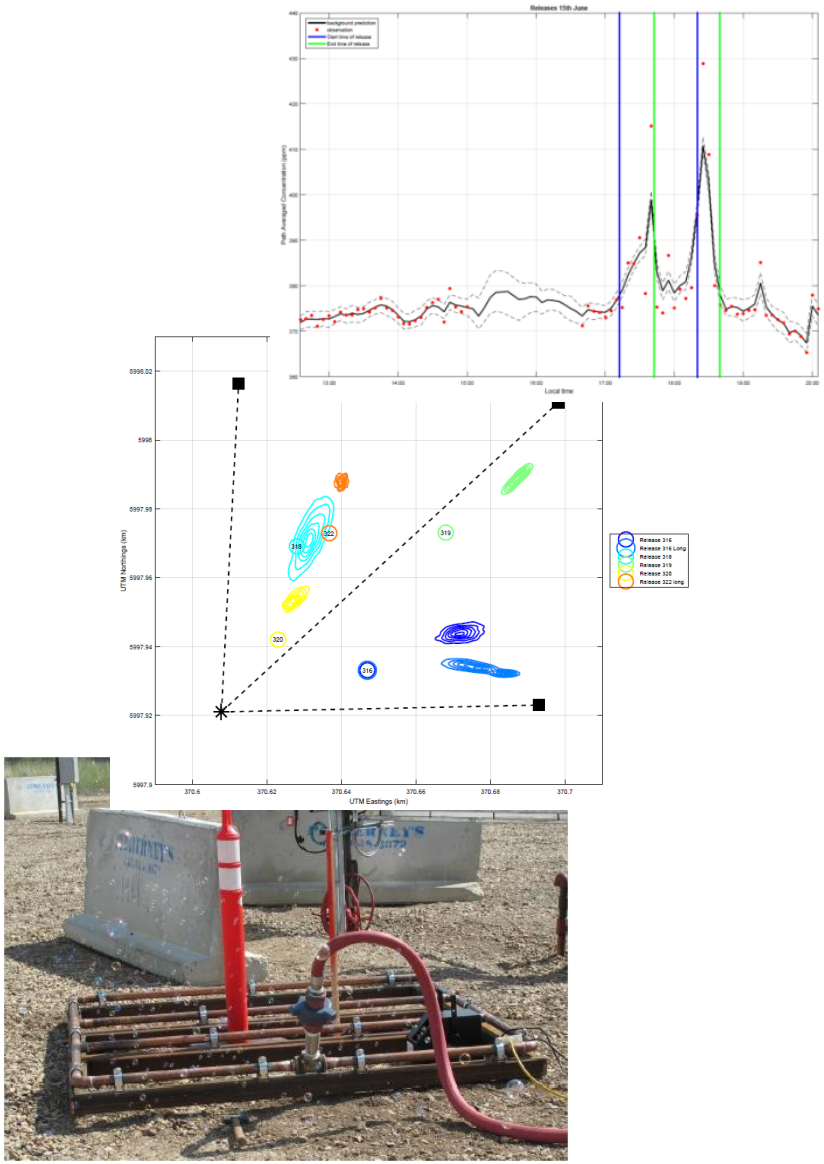
ATMOSPHERIC MONITORING

from Hirst et al. 2015

- The high variability of CO_2 levels in the atmosphere makes detecting small emissions difficult
- LightSource system installed and functional at all injection sites
- Release tests demonstrated we can detect and quantify CO_2 emissions on the well site
- **Confirmed as technology for atmospheric monitoring at Quest**



from Hirst et al. 2015

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PERFORMANCE & CLOSURE

Closure Plan Outline
Intro
Project Overview
Storage Performance Tasks for Site Closure - CCS Targets from the Regulator
Storage Performance Data - Well inventory - CO_2 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

Post Injection MMV:

- Complements data collected during baseline and injection periods to demonstrate clear understanding of performance history
- Continues to validate the modelling of future CO_2 behaviour
- Assures decommissioning of the wells
- Facilitates the safe handover of liability, minimize future concerns
- Time frame is determined by assessment of remaining risk: site specific

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MMV KEY POINTS

Important considerations for an MMV plan:

- Containment – risk based:
  - Thorough risk assessment required
  - Trigger based – each technology must contribute to specific barriers
  - Wellbore risks prior to abandonment generally higher than geologic risks, hence more intensive monitoring
- Conformance – confidence in storage security:
  - Model driven: need to acquire sufficient data to provide confidence in the model
  - Post-injection monitoring period dependent on site risk and operational performance
- Public/Stakeholder confidence
  - Perceived risks need to be treated seriously

➡ Site selection critical to risk assessment – MMV must be risk-based and site specific

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- Partners: Chevron Canada Ltd & Marathon Oil Canada

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