CaMI Field Research Station: Shallow CO2 release monitoring

Don Lawton\textsuperscript{1,2}, Kirk Osadetz\textsuperscript{1} and Amin Saeedfar\textsuperscript{1}
\textsuperscript{1}Containment and Monitoring Institute \& \textsuperscript{2}University of Calgary

Calgary, CANADA

IEAGHG Monitoring and Modelling Workshop July 8, 2016
Field Research Station (FRS) : Location

10 year land lease from Cenovus Energy
¾ section
(480 acres
194 hectares)
CaMI/UofC – Field Research Station (FRS)

- Undertake controlled CO₂ release at 300 m (Phase 1) & 500 m (Phase 2) depth; up to 1000 t/yr
- Determine CO₂ detection threshold for different monitoring technologies
- Monitor vertical and lateral gas migration at intermediate to shallow depths (CO₂ and CH₄).

![Diagram of CO₂ injectors and observation well(s) at different depths.]
Stakeholder engagement
FRS Phase 1 layout plan

- Surface seismic grid
- Injector well
- Observation well
- Groundwater well
- Seismometers
- Classroom
- Instrument shed

Access road

ERT array & fibre optic

3C-3D seismic array

1 km
Stakeholder engagement
Phase 1 logs

102

10-22

103

Above_BBRS (New)

BASAL_BELLY_RIVER_SST

Pakowi
FRS#1 300 m injection zone: Cores

Cap rock

Reservoir
FRS mud gas analyses

Analyses courtesy Bernhard Mayer, AGL, UofC
FRS Phase 1 layout plan

- **Surface seismic grid**
- **Injector well**
- **Observation well**
- **Groundwater well**
- **Seismometers**
- **Classroom**
- **Instrument shed**

**Access road**

**ERT array & fibre optic**

**3C-3D seismic array**

1 km
FRS baseline seismic volumes

Isaac and Lawton, Interpretation (in press)
FRS baseline seismic volumes

PP - inline

PS - inline
FRS first groundwater monitoring well

June, 2015
70 m depth

Courtesy Aaron Cahill, G360, University of Guelph

$\delta^{13}$C CO$_2$ = -19 per mil
Dissolved CO$_2$ = 18 mg/L

$\delta^{13}$C CH$_4$ = -84 per mil
Dissolve CH$_4$ = 25 mg/L

TDS: 2550 mg/L

Analyses courtesy Bernhard Mayer, AGL, UofC
FRS regional seismicity
FRS geostatic model - porosity

COUNTESS 10-22

Basal BBRS unit

- FOREMOST
- BASAL_BELLY_RIVER_SST
- PAKOWKI
- MILK_RIVER
- COLORADO
- MEDICINE_HAT
- SECOND_WHITE_SPECKS
- BASE_FISH_SCALES
- BOW_ISLAND
FRS Phase 1 reservoir simulation

After 1 year injection

After 5 years injection

After 1 year post-injection

After 5 years post injection
Observation well (1)

- Located 30 m northeast of injector well
- Depth 350 m
- 120 m steel surface casing; 4.5” steel production casing
- Integrated fibre optic cable capable of distributed heat pulse testing as well as distributed temperature sensing (DTS) and distributed acoustic sensing (DAS).
- Stainless steel U-tube for sampling reservoir fluids from the Basal Belly River Formation, or sampling through slotted casing. Pressure gauge at the injection zone.
- Above zone pressure gauge to monitor fluid pressure in an aquifer in the Upper Foremost Formation immediately above the McKay coal zone.
- Collaboration with Lawrence Berkeley National Laboratory
CaMI.FRS sand pack

Depth (m)

- 275
- 300
- 325

- cemented casing
- behind-casing sampling port
- uncemented sand pack behind casing
Observation well (2)

- Located 20 m southwest of injector well
- Depth 350 m
- 56 m steel surface casing; 4.5” fibreglass casing
- Integrated fibre optic cable capable of distributed heat pulse testing as well as DTS and DAS
- Experimental, helical-wound DAS fibre to increase DAS performance for vertical seismic profiles (VSP) and walkaway seismic programs.
- 16-level electrical resistivity cable with electrodes mounted on outside of the casing.
- 24-level geophone array, with nodes at 5 m spacing, for VSP acquisition and micro-seismic monitoring during injection.
- Collaboration with Lawrence Berkeley National Laboratory
FRS Phase 1 wells

Monitor 1 (geochemistry)

CO$_2$ injector

Monitor 2 (geophysics)
FRS borehole – surface baseline

Magnetometric resistivity

Bernard Giroux, INRS, Quebec
Mobile geochemistry laboratory

- Sondes for field measurements (pH, EC, T, DO, Eh)
- Soil gas flux chambers and soil gas collection probes
- Gas chromatographs for hydrocarbon and soil gas analyses
- Ion chromatograph (Dionex) for anion and cation concentration analyses on water samples
- Titrators for alkalinity and H$_2$S in water samples
- Portable H$_2$S gas analyzer
- Carbon isotope laser analyzer for methane
- Carbon and oxygen isotope laser
Resourcing & collaborations

- Alberta, capital & operating
- Govt of Canada Western Economic Diversification
- University of Calgary
- Natural Resources Canada
- Industry CaMI JIP subscribers

- Schlumberger Carbon Services
- Canadian CMC research groups
- US Department of Energy - LBNL
- UK Carbon Capture and Storage Research Centre
- NTNU Norway
- CMR & SINTEF Norway (under CLIMIT application)
- GFZ Germany
Timelines

- Surface CO$_2$ handling facilities – end of July
- Surface monitoring equipment trenching – early August
- Facilities permit – early August
- Injection permit – end of August
- Baseline surveys completed – end of August
- CO$_2$ delivery – September
- Injection start: end of September
Discrete monitoring – geophysics and well logging

- 3C-3D surface seismic surveys using 500 CaMI nodes and fibre-based sensors
- Vertical seismic profiles – both permanent sensors and removable (Dave Eaton)
- Cross-well seismic surveys (LBNL)
- Cross-well electromagnetic surveys (LBNL)
- Surface-borehole electromagnetic surveys (LBNL)
- Surface-borehole electrical resistivity surveys (LBNL)
- Magnetometric resistivity surveys (INRS)
- Time-domain electromagnetic surveys (INRS)
- Pulsed neutron logs
- Borehole sonic logs
- Borehole induction logs
Discrete monitoring - geochemistry

- Atmospheric monitoring leakage program
- Groundwater sampling from domestic well
- Groundwater sampling from multi-level wells
- Soil gas (CO$_2$ and CH$_4$) monitoring with up to 24 soil gas probes
- Soil gas (CO$_2$ and CH$_4$) monitoring using 12 moveable soil gas flux measurements
- Surface casing vent flow monitoring
- Observation well fluid sampling and analysis
- Tracer studies including ‘doped’ CO$_2$ with a trace of thermogenic methane
- Tracer studies including noble gases (collaboration with Edinburgh University, UK)
Monitoring methods to be evaluated

- High resolution GPS
- Interferometric synthetic aperture satellite radar (INSar)
- Surface tilt-meter array
- Borehole-based muon tomography
- Optical-fibre chemical sensors (CO$_2$ and CH$_4$)
- Continuous seismic sources
- Surface DAS (trenched)
GPUSA – continuous seismic sources

Funding application submitted to USDOE SUB-Ter program by GPUSA

MicroVib™ Linear Vibration Seismic Source

MicroVib™ Packs the Power of Vibroseis into a small, low cost, Permanent Downhole Seismic Source

GPUSA’s (Patent Pending) MicroVib™ Seismic Source Features:

- Generates a peak force of 4800 pounds at 200 Hz.
- Powered by compact, shock-resistant, 5 horsepower, maintenance free electric motors
- Produces linear vibration similar to vibroseis
- Reduces 95% or more of the attenuation seen by surface sources, effectively putting more energy on the target than a 50,000 pound-force surface source.
- Rugged, high performance digital accelerometer provides data for real-time QC monitoring and for correlation processing (deconvolution)
LBNL continuous surface seismic source

Contingent on funding in 2016-2017

$0 \rightarrow 80$ Hz

10 T-force rotary source sitting on a 1 m x 2 m x 2 m deep foundation

$F = Mr\omega^2$

Reference geophone amplitude during a 0-80 Hz sweep, 1 minute up, 1 minute down

Australian Otway Project images courtesy of LBNL, Curtin University and the CO2CRC