Project Outline

Title: Processing of passive seismic datasets for stress induced events CTSCO17-07		Demo supported research:
Project Number: *ANLEC TBD* **Status:** Under Development	**Project Commencement Year:** 2017 **Project Completion Year:**	**Proponent:** CTSCo

The Context:

This project is aimed at supporting CO_2 storage projects in Australian sedimentary basins, with initial emphasis on the CTSCo Surat CCS demonstration project. The Surat CCS project proposes to source 180,000 tonnes of Greenhouse Gas Stream derived from a Huaneng PCC attached to the Millmerran Power Station in south eastern Queensland. The GHG Stream will be injected at 60,000 tonnes per annum for three years into the low salinity groundwater of the Precipice Sandstone.

A central component of CCS projects is the need to monitor and verify the extent of the injected CO_2, both in the storage reservoir and in the overlying rocks (to the surface environment) to provide assurance to the Regulator and stakeholders that the plume is behaving as predicted and that no environmental harm has been caused by leakage.

Real-time, surface-deployed single or array geophones for passive seismic monitoring is a potential technique to locate elevated ambient seismic activity and to help inform in-situ stress conditions, injection decisions and contribute to safe, secure subsurface containment. To be of greatest value, passive seismic monitoring should be conducted prior to CO_2 injection to enable baseline and comparative studies during and after injection.

With current Nodal-geophone technology, passive seismic surveys are now available to be recorded as a very low-cost add-on to conventional 3D seismic surveys.

CTSCo has applied this opportunity and recorded arguably one of the first such 3D single phone surface passive seismic recordings of high-sample density, designed to baseline the natural seismicity prior to injection operations (acquired as a “piggy back” survey to the conventional high density, fully azimuthal Glenhaven 3D Seismic Survey).

The passive dataset will be processed and interpreted after the conventional data is interpreted, over the next two years.

The Problem Statement or Information Gap:

CTSCo acquired the 10,055 station passive seismic survey as a baseline survey prior to CO_2 injection in July 2015. The objective of the survey is to detect pre-existing faults, micro fractures/cracks, high density seismicity, anisotropy and stress for the interval between ground level and the base of the Precipice Sandstone prior to CO_2 injection. The results of the processed passive seismic survey data will provide information on:

- the geomechanical strength of the Precipice Sandstone;
- the capability and the integrity of the Evergreen Formation seal;
- the preferential plume movement due to anisotropy, stress direction and micro fractures/cracks between the surface and the base of the Precipice Sandstone storage reservoir.

A monitoring passive seismic survey will be conducted after CO_2 injection. The comparison between the baseline and monitoring surveys will provide information on potential geomechanical deformation due to pore pressure changes and CO_2 plume movement.

Passive seismic processing is new technology. A limited number of companies in the industry have the ability to process these datasets. Each company has its own technique. CTSCo requires the processing company to process the passive seismic data using the best and latest Tomographic Fracture Imaging technology or Brightness Method or Ambient Noise Surface Wave Tomography or diffraction stacking methodology or double difference tomography method.

The Glenhaven Passive Seismic Survey comprises:

- 10,055 Nodal geophones at 10 metres spacing along receiver lines at 100 metre spacing within the 10.km^2 area.

Data were recorded at 1 msec sampling interval, 24 hours a day for 6 days (including active Vibroseis recoding approximately 7 to 8 hours/day). The volume of data recorded amounts to 20Tb.

The following data sets are available to be integrated into the processing of the passive seismic. .

- Stacking and Migrated Velocity Volumes – at 5 m intervals
- Azimuthal Stacking Velocity Volumes (anisotropy velocity model) – four separate volumes
- ETA volume
- Elevation and surface statics
- Well sonic and density logs and checkshot (one well, West Wandoan-1)

The Research Objective:

- To process the passive seismic data using latest technology in order to identify pre-existing faults, micro fractures/cracks, high density seismicity, anisotropy and stress within the Glenhaven 3D seismic survey.
- To integrate the result of the passive seismic survey into the conventional Glenhaven 3D seismic survey

The main risk with the CTSCo dataset is that the potential lack of discernible natural seismicity and potential "elevated ambient seismic activity" from nearby CSG operations.

Products/Outcomes

- Cumulative seismic activity volume
- Tomographic Fracture Imaging or Brightness Method volume
- Fracture density volume/maps
- Anisotropy volume/maps
- Shear and compressional wave velocity model volumes

The project is designed to maximise the identification and understanding of information present in the passive dataset that is highly relevant to the issues of lower cost options for M&V of the plume extent and of providing the basis for demonstrating, and quantifying, the magnitude of the presence/absence and induced seismicity and geomechanical deformation arising from CO_2 injection.

Innovation added value

Given that passive seismic data can now be recorded as a very low cost add-on ("piggy back") to conventional 3D seismic survey, the results may provide a useful additional surface-based tool for lower cost M&V in industrial deployment.

Ability to compare natural passive seismicity events with anisotropy derived from high density conventional azimuthal 3D seismic survey over the same area.

The generic results of the project, in terms of processing sequences, QC steps and methodologies at each stage of processing and output volumes should be applicable to other land-based CO_2 injection sites.

Work programme:

The following outputs should be produced:

- Cumulative seismic activity volume
- Tomographic Fracture Imaging or Brightness Method volume
- Fracture density volume/maps
- Anisotropy volume/maps
- Shear and compressional wave velocity model volumes

In order for the results to impact the Glenhaven Storage model the processing should be completed by end Qtr 1 2018

Data acquisition:

The passive seismic recording was part of the conventional Glenhaven 3D seismic survey. The passive seismic recording was recorded over 6 days at an average of 16 hours/day without vibrator source.

The following is the acquisition parameters for the conventional survey:

Acquisition parameters:

Geometry

Spread Geometry	Triple Staggered Orthogonal
Number of Receiver Lines	34
Total Receivers	10,055
Receiver Density	990.64 / km²
Receiver Line Interval	100 metres
Receiver Interval	10 metres
Staggered Receiver Points	-3.33 m, 0, +3.33 m
Receiver Line Bearing	96.75 Degrees
Number of Source Lines	35
Total Source Points	10,273
Source Density	1,012.12 / km²
Source Line Interval	100 metres
Source Interval	10 metres
Staggered Source Points	-3.33 m, 0, +3.33 m
Source Line Bearing	6.75 Degrees
Natural Bin Size	5.0 m x 5.0 m
Recording Patch	Fixed spread; all receiver lines / receivers active
Number of live channels	10,055 channels
Minimum Offset	2 metres
Maximum Offset	4,780 metres
Maximum Fold	966
Total Surface Area	10.15 km² (preplot) - 10.273 km² (final)

Recording System:

Instrument	FairfieldNodal - ZLand 1C (second generation) Nodal
Seismic Data Channels	1
ADC Resolution	24 Bits
Sensor	Single Vertical Geophone
	Natural Frequency 10Hz
	Critical Damping 70% (78.7 V/m/s)
Battery	Rechargeable Li-Ion
Charging Temp	+3°C to + 40°C
Charging time	Less than 3 hours
Passive recording	24 hours
Sample rate	1 µ seconds
Low cut filter	1 Hz
High cut filter	200Hz, Linear, (0.8 Nyquist)
Notch filter	Out
Correlation	Zero Phase, Correlation before Stack
Recording Media	External Hard Disk Drive
Data Format	SEG-D, 8058 IEEE Demultiplexed
Normal Vibroseis data format	Raw and correlated data were saved
Passive Data format	30 seconds receiver gather (Raw data)
Drive Level	80%

Receiver position tolerance: Receiver position tolerance in the orthogonal direction is ±2.5 metres. All receiver positions must be surveyed to an accuracy of ±1 metre in the XY direction.